PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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Editor

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THE LOOK BOX

ACCOMPLISHMENTS of the Office of Rubber Director are the more outstanding because of the delay and uncertainty which marked the early efforts to move into actual plant construction. It seems appropriate to admit that the early handling of affairs in rubber fell little short of scandal. Now the agency has finished its work and is ready for liquidation.

Well Done

While three industries, rubber, chemistry and petroleum, deserve some credit for the accomplishment, in large measure the credit goes properly to two men William M. Jeffers and Bradley Dewey. The former left a railroad job, read the Baruch report, accepted it as a mandate and went to work at getting plants built. In his own words he "bulled it through."

He named Dewey as assistant director to handle technical matters and gave them no further attention. When the plant construction was assured, Jeffers resigned so Dewey could continue as director.

Knowing when a job is finished seems to be a good habit in the affairs of rubber.

Chemical rubber as an industry, however, is just started. What has been done has come about under necessity and without regard to cost. The one purpose has been rubber, which is now being made in sufficient quantity.

It is to be hoped that supervision does not return to the new industry. From here it should win on its merits. Chemical rubber has superior qualities on which it can hold position over natural rubber. Thus far it is not superior and cheaper in all uses. It is not certain that it will make the cheapest and best tire. But it does have superior position in so many other uses that it can be maintained by private industry and in competition with the plantations on the Malay peninsula.

The chemist has only started with his elastomers. With the plants that are essential to the new industry he can bring his chemical product into full competition with natural rubber. When he wins on that basis, the country will have a new industry.

IT SEEMS crystal clear that majority opinion in the United States expects full employment as a right of the individual. Whether this is sound or unsound, wise or foolish, possible or impossible are at the moment secondary considerations. No one can read the platforms of the two dominant political parties and interpret the speeches at their two recent conventions without coming to the realization that full employment is now an obligation.

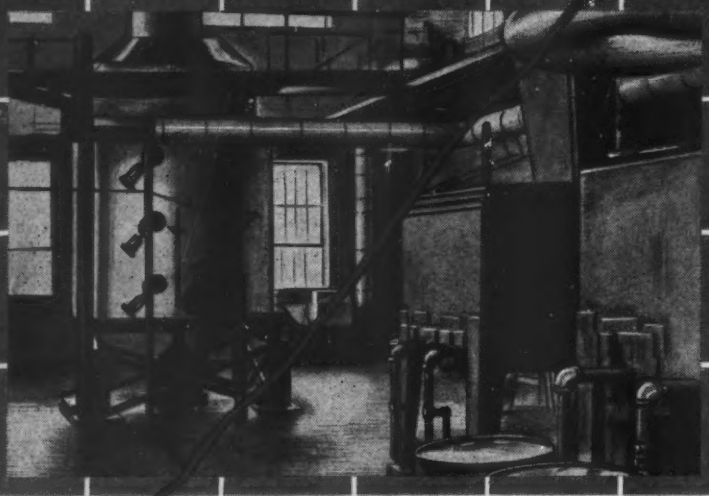
Job for Industry

There is simply a dominant conviction that work must be provided for men and women who are willing to work.

Under the pressure of war requirements jobs have been assured on this proposition in the democracies. There have been other references to the fact that in Russia work is accepted as the right of the individual. The trend of this thinking has been constant over a period. Now it is a part of the political, industrial and economic philosophy and its consequences must be accepted.

Nothing seems fairer than the proposition that work be available to those who desire it. Difficulties arise when the matter of assuming the obligation of providing work is examined. When a man demands work it comes close to agreeing that he will accept what is provided. Only by tempering his demand can he shape his activity.

Dowtherm on the job!



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In the matter of obligation some of the recent speeches in Chicago had it after this fashion:

"If business can not provide jobs, the government will."

That is simply a threat from the political front. It can not be ignored which is one reason for its inherent danger. Even the man who assumes that the right to employment is inherent should be careful from whence his beneficence comes.

Work can be provided by appropriating public money and designating projects. A lot of that has been done. That is fundamentally the basis of the high employment rating of the war-production period in the United States. Men who look to that accomplishment should in fairness to themselves examine the deficit that piles up in public debt. The necessity of building military equipment is not to be questioned. It is in order to question the procedure as sound economics. Debts must be paid whether public or private.

Unfortunately the demand for full employment has been grasped by what is unfairly classed as labor. The politician has made the division. He assures one set of men of their right to employment and at the same time threatens another set. Perhaps some progress could be made if the men who accept payment for employment realized that the other side of industry, management, just as keenly desires full employment.

Full employment is as much to the advantage of one segment of industry as to another.

It would be a bold and valuable move if some far-seeing labor leaders and some far-seeing management leaders took themselves into a hall and locked the politicians out and gave the proposition of full employment a thorough going over on the proposition that the obligation rests on industry.

The man who has a few dollars invested in a lathe is as anxious to keep it turning as is the man who stands before it while it turns. It will keep turning so long as what it makes can be disposed of at a price sufficient to pay all costs of operation, maintenance and replacement. When that fails and a deficit begins to pile up, the spinning days of the lathe are numbered, regardless of where the deficit is charged.

Too Many Remedies

THE more the effort to benefit small business, the more small business needs aid. Such is the record of the legislative attempts in assisting what the politician calls "the little man." Still it is a lesson never heeded, for the efforts at helping little business grow in number while the few that become law bury little business under hopeless confusion.

Recently a radio report out of Washington paid tribute to some committee which was striving to extend the life of OPA and at the same time include a remedy for "the little man." No one seemed to give thought to the possibility that what previously had been done under OPA had made it difficult for "the little man" to do business.

In fundamentals there is no difference in business, big or little. Any curb on big business likewise harms little business. Should little business find benefit from legislation, the benefit will extend to big business.

It may be that there is no such thing as little business or "the little man."

An Extra Dividend

EXTREME satisfaction must come out of the instances wherein knowledge of first-aid methods permit men to save lives. This training is accepted as part of good working conditions and its value is based on what it will do when industrial accidents occur.

Frequently, however, an accident far removed from working routine has its happy ending simply because some man trained for industrial mishaps is at hand. One recent instance came to W. O. Pyeatt and C. M. Mayfield of the Amarillo plant of The Texas Company. A paragraph from the July issue of the Safety Digest gives this brief report:

"Witnesses who had removed one of the girls from a ditch filled with mud and water thought she was dead but Pyeatt immediately started artificial respiration. The unconscious child was revived after a few minutes and taken to the hospital in an ambulance."

"Markets are not developed or production justified by promises that are in conflict with the fundamental law of supply and demand. If the full employment planners would come down to earth long enough to see that consumer demand must occur before useful and profitable employment can ensue—and that violent and destructive fluctuations in employment can only be dealt with by cooperative effort in industry to foresee and forestall these fluctuations, and not by mere exhortation to industry to operate irrespective of demand—then we shall understand where to apply our efforts in developing a sound economy and a healthy social structure.

"The real problem is one of making the most intelligent and efficient use of all our national resources. In dealing with these postwar problems we shall find that there are many things that can be done better by voluntary cooperation than they can by individuals or by government directives. It is easy to put the brakes upon industry. But industry goes ahead as a result of incentives—and not by repression or compulsion. The unemployed cannot be put to work—or kept at work —in any other democratic way."

GEORGE A. SLOAN, *President, Nutrition Foundation.*

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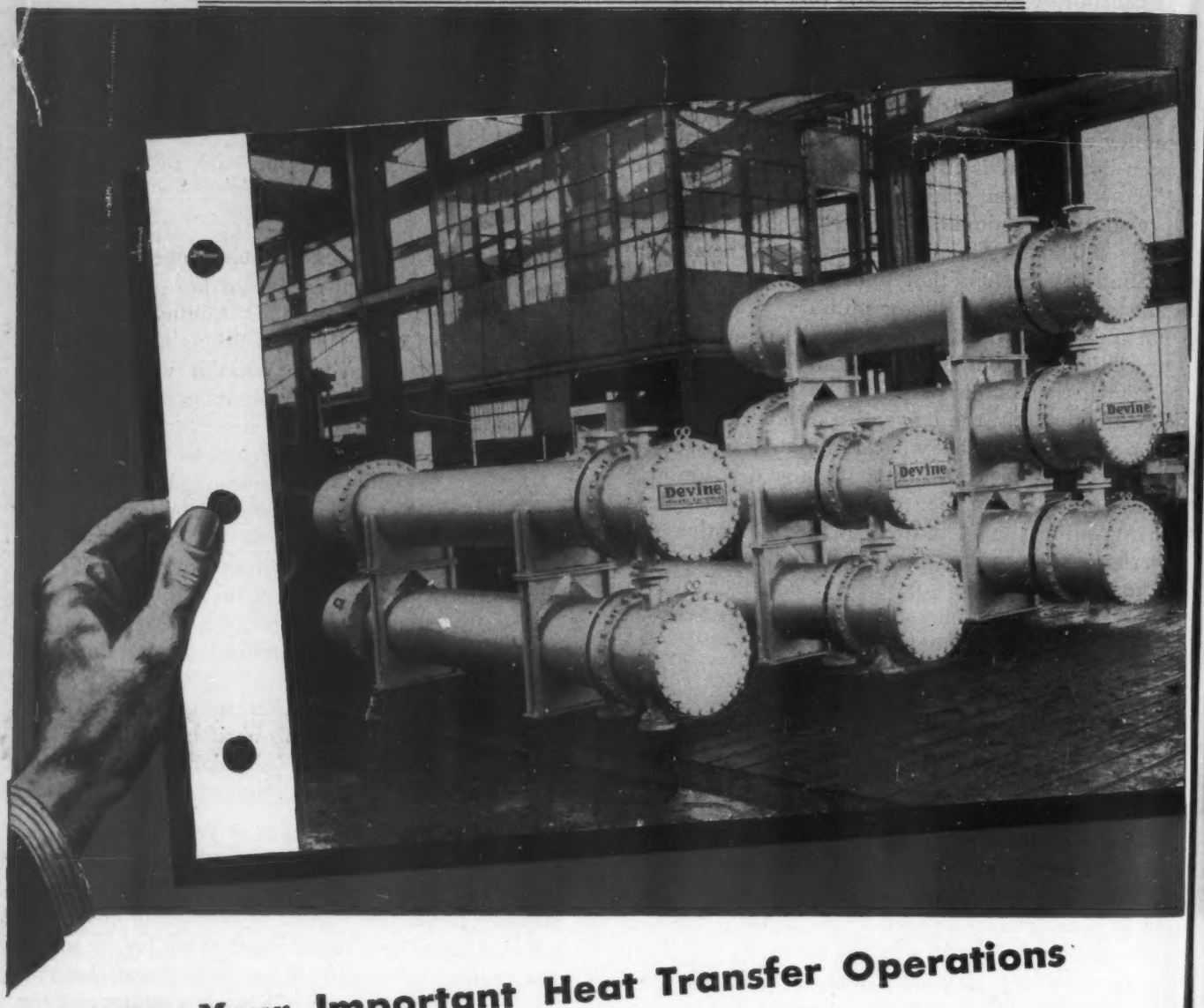

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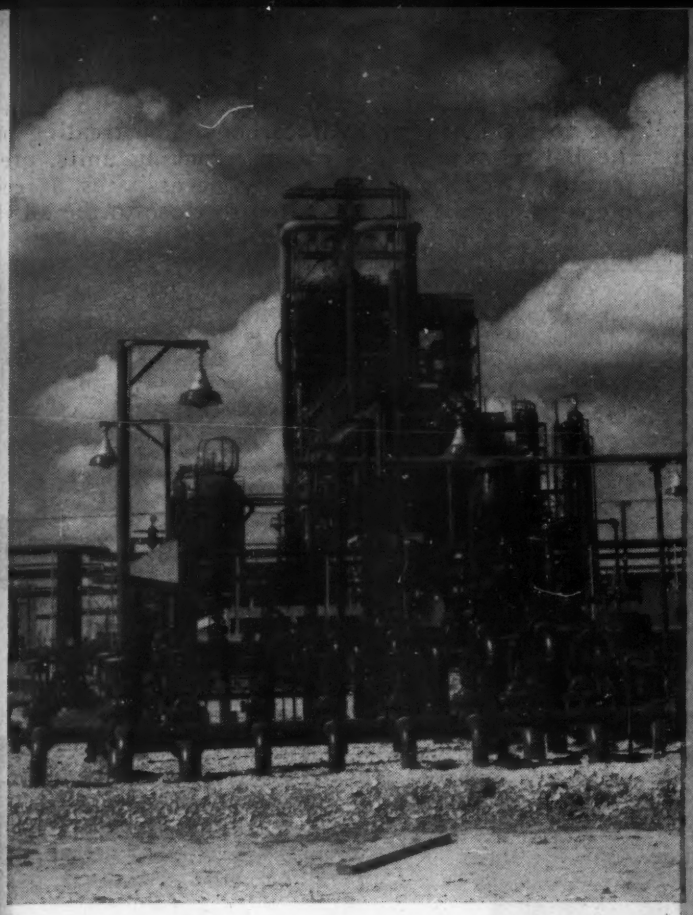


What happens in an Alkylation unit if several pumps have to be shut down for an hour or more? The unit must suspend production of aviation alkylate. Correct—but not "right" while so much depends on on our air superiority. To be assured that these pumps do not let us down, it is well that their peculiarities be made known for all those interested in refinery operation.

Alkylation-Unit Pumping

IRVING TAYLOR, The Lummus Company

THE product made at most refinery Alkylation units form the backbone of present-day 100-octane aviation gasoline.* For although this alkylate constitutes something less than 50 percent of the final product, its octane number is high enough, with lead, to permit incorporation of large percentages of lower-octane base stocks.

Pumps, as a group, are the heart of any refinery unit, so alkylation-unit pumps being in such a vital spot, ought not to be taken for granted. Inasmuch as they do have a few peculiarities which could stand some clarification, the subject may justify the space, paper, and print for a short article.

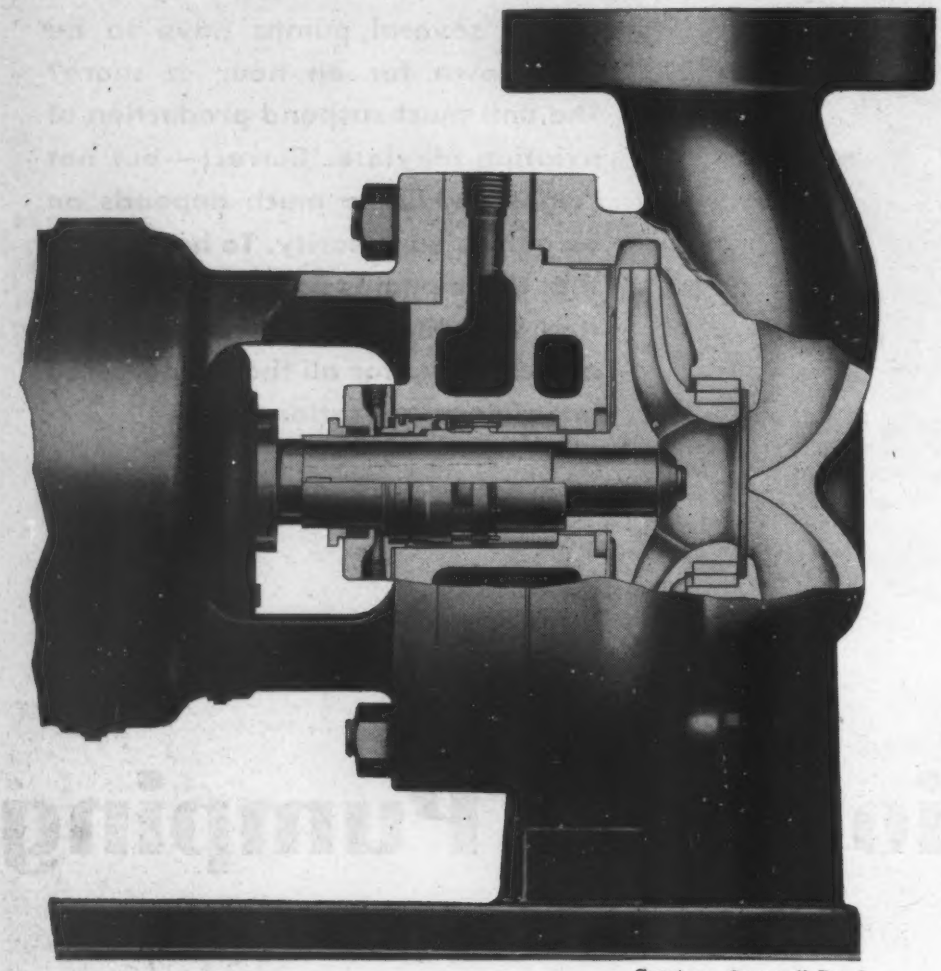
It also happens that the problems encountered in getting alkylation unit pumps to operate satisfactorily are to a large extent duplicated in butadiene-from-petroleum plants, in the gas plants installed with new catalytic "crackers," as well as in feed preparation, isomerization, and depropanizer additions. Thus it will be seen that a very large share of recent refinery-pump applications differ from those in cracking units, topping units, and lube-oil plants. But the reader who finds himself more closely as-

Refinery men wish that the pump manufacturers would give more consideration to the packing box problem when modifying their pump designs. The manufacturers would like to have their pumps adapted to use either packing or seals, granted. But it is probably easier to change a pump designed for mechanical seals over to the use of packing than it is to change a conventional packing box over to use a seal. Therefore such parts as the gland or outer seal plate, the throat bushing, the shaft sleeve, and the machined surfaces of the box itself ought all to be properly planned and precisely machined whenever a seal is furnished in a new pump. Seals cannot be expected to work satisfactorily when pumps are furnished with loose bushings, too few gland-bolts, or slightly rough surfaces at the joints and faces.

Alkylation unit pumps are pointing the way to a better pump and a better way of life.

* This article considers primarily alkylation units using butylenes and acid catalysts to produce iso-octane, rather than the thermal alkylation process which is used to produce neohexane for instance.

sociated with one of these other units will recognize, in the following discussion, the pump applications and problems which are similar to his own, and so the subject will be limited to the sulphuric-acid and hydrofluoric-acid alkylation units from here on.



Courtesy, Ingersoll-Rand

Single Cameron shaft seal as installed in a single-stage process pump, handling light hydrocarbons.

Pumping Categories

Pump applications in acid alkylation units can, for the most part, be confined to four general pumping categories, as follows:

(a) Light hydrocarbons.
(b) Concentrated acids, and also (on hydrofluoric acid units)—light hydrocarbons with trace of hydrofluoric acid.
(c) Cooled mixtures of acid and hydrocarbons. (Large capacities, low heads.)
(d) "Utilities" (caustic or water).

Before taking up these categories for closer inspection (leaving out the last one, as pumps for handling caustic or water are not peculiar to alkylation units) an attempt will be made to describe briefly what an alkylation unit does, how its pumps are arranged and selected in general, and what the main pumping problem is.

Feed Preparation

Both the sulphuric-acid and the hydrofluoric alkylation processes have the same general flow scheme. In each the so-called B-B charge is a treated mixture of butanes, butenes, butylenes, etc. These are light fraction "by-products" from the cracking units, gaseous at normal temperatures and pressures, not suitable for inclusion in high-octane fuel unless they can be properly polymerized or "condensed" with isobutane to form heavier hydrocarbons. The treating of the B-B cuts from the various cracking units, preparatory to alkylation, usually necessitates a feed preparation unit which is often so close to the alkylation unit and so interconnected in certain respects, as to be practically a part of it.

Flow Scheme

The treated B-B is continuously pumped into the acid-contacting or reactor portion of the alkylation unit. Two other streams are also continuously pumped in, along with the B-B, these being the concentrated acid catalyst needed to promote the reaction (H_2SO_4 or HF) and recycle iso-butane. Here are formed some iso-octanes by condensation with iso-butane from the various "Bs" charged, not without generation of some heat which must be continuously removed. Here must be large-capacity pumps functioning as mixers, to force a circulation, thus hastening the contacting throughout the mixture and permitting efficient removal of the heat.

Frequently these circulation pumps are built into the reactors or "contactors" as are also the cooling tubes; such integrated reactor units in that case being furnished by Stratford Engineering Corporation, along with all the necessary auxiliaries which will be discussed below. Otherwise the circulating pumps are most likely to be horizontal propeller-type, each placed near the reactor and chiller, in a group. Refrigeration equipment, with either centrifugal or reciprocating compressors, also is re-

quired in this area on sulphuric-acid units, whether using Stratford contactors or separate chillers. For the hydrofluoric-acid units, however, water-cooling in the contactors is sufficient to remove the heat.

When the combined mixture of hydrocarbons and acid leaves the reactors or the contactors, the acid has to be separated out, most of it mechanically, in settlers, whence it is recycled to the reactors. Neutralization of the hydrocarbons follows, by caustic scrubbing in H_2SO_4 plants. The corresponding equipment in HF plants includes an acid-stripper column, followed by bauxite treaters. In addition, the HF plants have their own acid-regeneration section, whereas spent H_2SO_4 is more apt to be withdrawn for other uses.

The remainder of the alkylation unit is the part which covers the most area, has the most towers, exchangers, and the largest number of pumps. This is the fractionation section, wherein the aviation alkylate is finally separated and the excess isobutane which has not entered the reaction is separated and recycled to the reactor section, leaving as by-products normal butane, propane, pentane, and a small percentage of "heavy alkylate." There need be no oil-heaters in the usual alkylation unit, since the bottoms of the towers can all be heated sufficiently by reboilers, utilizing process steam.

If an isomerization unit also is installed near the alkylation unit, as is sometimes the case, then the normal butane by-product just mentioned can be isomerized to make additional iso-butane, thus increasing the ultimate yield of aviation alkylate in plants where an isobutane shortage exists. Several of the newest 100-octane-gasoline refineries have been arranged so that their feed preparation, alkylation, and isomerization units are built in one area as an integrated trio. This arrangement sometimes makes for one pump house enclosing the 45 to 50 pumps which serve all process duties in the 3 units except for the reactor section of the alkylation unit. This section, with its acid pumps and auxiliaries, should be kept apart for reasons of safety.

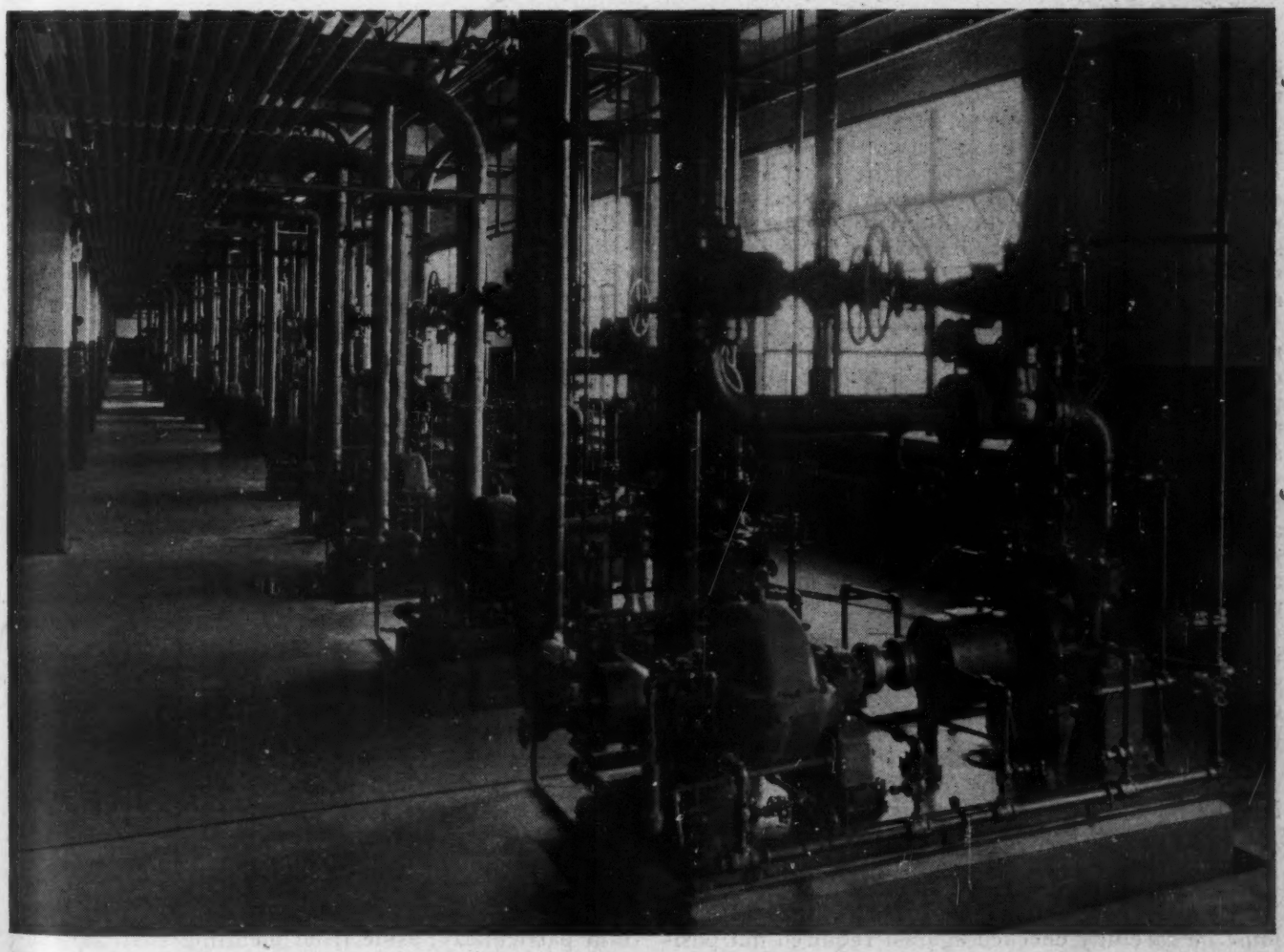
TABLE 1
Alkylation Unit Pumping

Fractionating Section Pumps	Pumping Temp., °F.	Capacity GPM	Discharge Pressure p.s.i.	Suction Pressure p.s.i.	Diff. Pressure p.s.i.	Viscosity
The Majority.....	Less than 150	Less than 500	Less than 200	50 to 120	Less than 100	Negligible
Few Highest.....	375 to 400	800 to 2000	350 to 500	225 to 400	250 to 400	Negligible

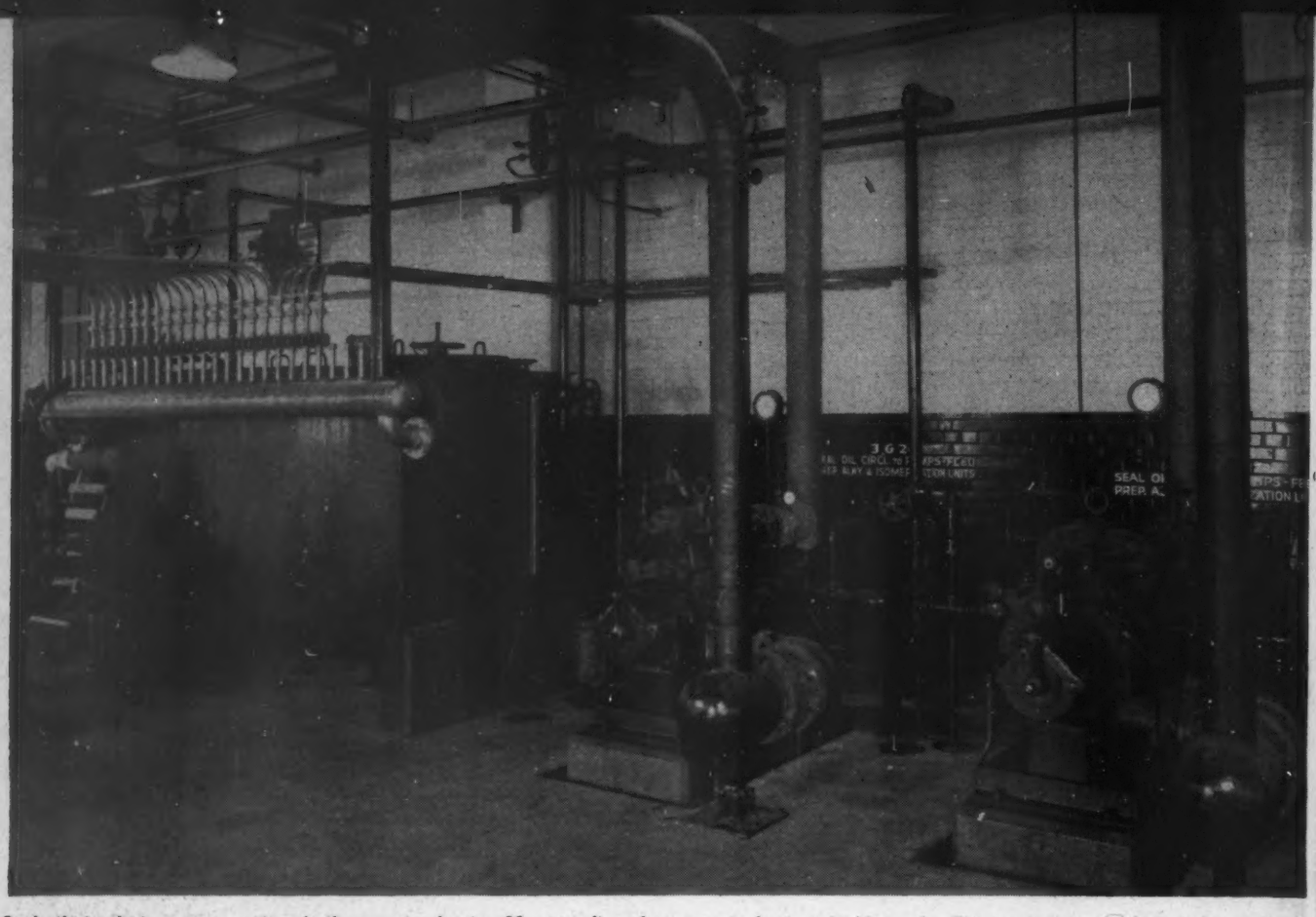
Selection and General Construction

There are no hot-oil pumps in the average alkylation unit. The highest pumping temperature likely to be encountered is around 375 to 400° F., and this on only one or two pumps. Most of the pumps handle liquids below 150° F.

Since the discharge pressures are low to moderate, and suction pressures moderate to high, the result-



Some of the 48 pumps in a pumphouse serving a feed-preparation unit, fractionation section of an alkylation unit and an isomerization unit. The pump in the foreground has a single mechanical seal. Auxiliary piping on this pump is only for water cooling and venting.



Seal-oil circulating pumps and seal-oil reservoir, showing 20 return lines from pumps having double seals. This equipment would not be required for single seals.

ing required differential pressures are low, being mostly below 100 pounds. (See Table 1).

Specific gravities of the liquids handled in the fractionation section range between 0.45 and 0.70. Even at these low specific gravities the heads required for the centrifugal pumps do not become particularly high, because the differential pressures are so low. This factor (specific gravities) will influence the selection of the centrifugal pumps more than the reciprocating type however.

The services for which reciprocating pumps are more suitable than centrifugal are usually those requiring but little capacity, say less than 30 gallons per minute. Of course, there is no rule against using reciprocating pumps for some of the larger-capacity services too, (say up to 200 gallons per minute) where steam balance, personal preference, or other factors dictate the choice. However, when one does apply a reciprocating pump in the fractionating section, it should be a close-clearance, simplex direct-acting type, rather than a duplex or a motor-driven power pump neither of which operates well at reduced capacities on light hydrocarbons. Reciprocating pumps also may find application in the reactor section and in the "utility" services, pumping acids, caustic, water, or solutions. Power pumps and duplex pumps are satisfactory in these services.

Three more points affecting centrifugal pump selection which need to be touched on before exposing the main alkylation pumping problem, are

(a) NPSH (net positive suction head.)
(b) Driver horsepower
(c) Materials

Briefly then, available net positive suction head must be carefully checked against required net positive suction head for each pump in the fractionation section when purchasing, because many of the liquids handled are at their boiling points, leaving only the static head available above the vapor pressure. Driver horsepowers on pumps handling hydrocarbons should be considerably in excess of the required brake horsepower at pump design conditions, particularly for motor drivers, since the specific gravities may vary considerably, thus increasing the horsepower even if over-capacities are not demanded. (A too strict interpretation of the horsepower loading provision of Limitation Order L-221 at the time of purchasing motors for refinery pumps unfortunately has limited some vital units to interrupted and reduced production, by lack of excess horsepower.) The material of centrifugal pump casings for handling the light hydrocarbons would best be steel although cast iron is strong enough for the pressures involved. Steel would be justified as additional insurance against accidental breakage of cast-iron casings, which might bring about a truly terrible fire in an alkylation unit. In the case of pumps handling any hydrofluoric acid, even a trace, steel must be used for the casing and all wetted parts, for resistance to corrosion as well as for safety.

Since it was shown that the temperatures, capacities, differential pressures and heads were not out-of-the-ordinary for alkylation unit pumps, one might well ask, "What other factors are left to make these pumps any different from other single-stage refinery-process pumps?" (Most of them are single-stage centrifugals, to be sure.) The guilty factors are:

1. The low specific gravities.
2. The high suction pressures.
3. The acids.

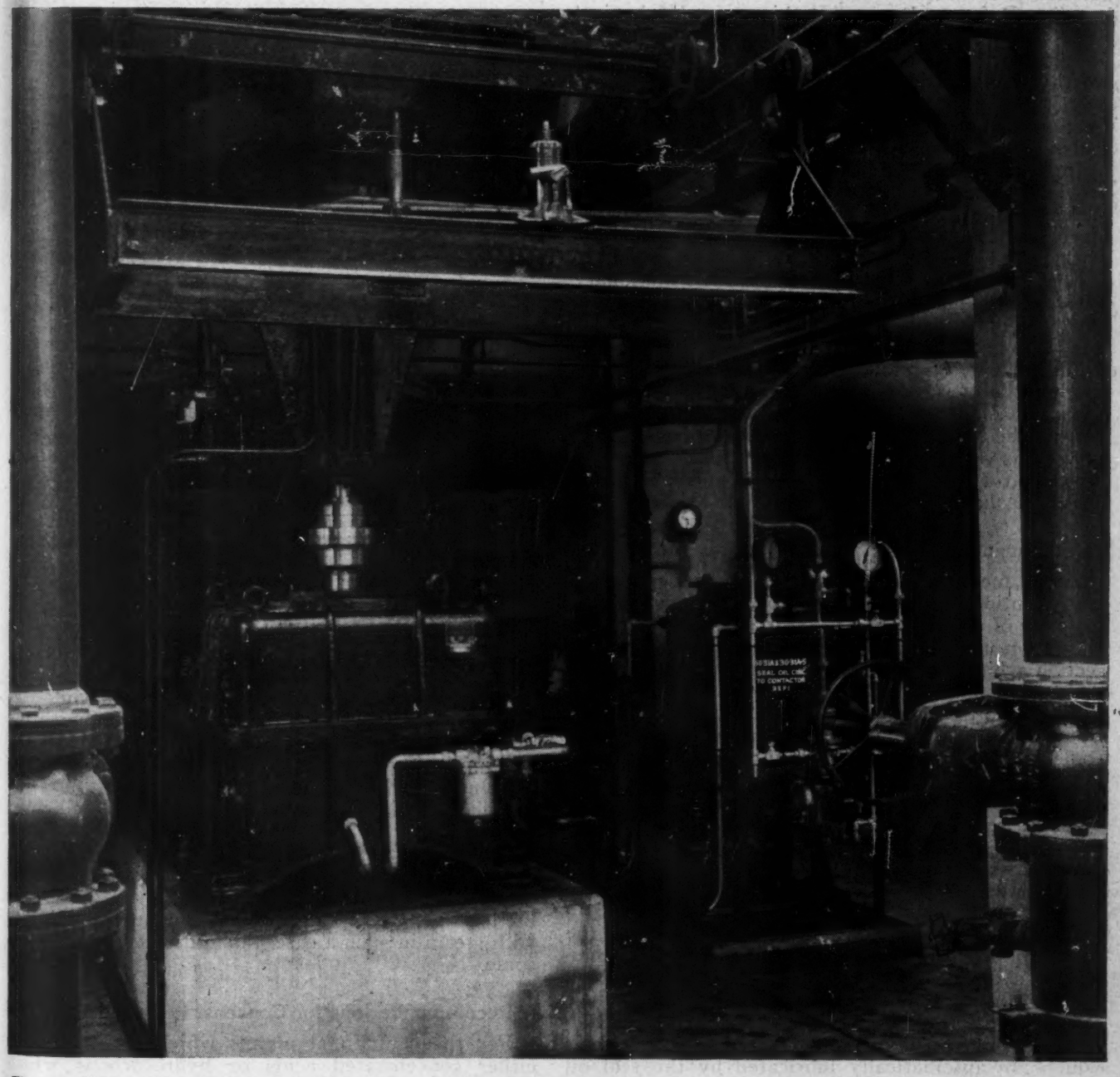
These factors do not affect the general construction particularly, aside from dictating that the centrifugals be vertically split so that circular joints can be used for greater tightness, but they do affect

one particular portion of the pumps and the auxiliaries pertaining to it—namely, the packingbox.

So the general construction of the centrifugal pumps, with the exception of the large-capacity mixing pumps in the reactor section, is not different from those in many other refinery processes, but the particular construction and care of the packingboxes is the alkylation unit pumping problem, and requires special attention.

This, of course, brings up the controversial subject of packing versus mechanical seals, and the proper arrangement for either case, upon which there is considerable choice. Recommendations will be made for each of the first three pumping categories listed near the beginning of this article. There are those who feel that packing can be applied satisfactorily to any pump packing box, and they would prefer not to use any mechanical seals. But even the packing proponents will admit that to pack against these light hydrocarbons or against the acids, a certain amount of auxiliary equipment is required to achieve satisfactory packing life, and this auxiliary equipment will include piping and sufficient valves or automatic pressure regulators to control whatever combinations of flushing oil, seal oil, injection oil, or bleed-off are necessary to keep the packing lubricated and protected. This is proof that the problem merits special consideration, and it offers the mechanical-seal promoters an equal chance to solve the problem, frequently with fewer auxiliaries.

Packing without these auxiliaries would not last long enough to be considered satisfactory, for it would either be eaten away by the acids or it would likely become frozen and hard on light hydrocarbons, due to the refrigerating effect of the trickle leakage vaporizing and expanding. It is of interest here that a German patent vested in the United States Alien Property Custodian as of October 1943, claims to prevent this freezing and hardening of packing by supplying heat to the place at which the evaporation



The propeller for this reactor-section circulating pump is inside the Stratford contactor at the top of the vertical shaft shown above the driving gear. Note unified seal-oil system at the right, which serves the double seal in the contactor's packing box.

and release of pressure takes place. Even this solution of the problem would require some auxiliaries, and if there are instances where it has been tried out in this country, they are not generally known.

It is unnecessary here to redefine the term "mechanical seal" or to describe the construction details of a seal. There were good illustrations and discussion in H. Hornschuch's article, "Why Mechanical Seals Improve Centrifugal Pump Operation," in "Power," August 1943. The presentation "Pumping Light Hydrocarbons," by Reuben G. Lovell (deceased) in PETROLEUM REFINER, April 1944, included a fine desciption of mechanical seals, although one might have obtained from it the impression that seals for light hydrocarbons did not come into being until hydrofluoric-acid alkylation units were built. (Actually the development and application of mechanical seals for such services has been going on for at least 8 or 9 years.) And again, in the California "Oil World" for March 1944, A. Hollander gave a detailed and valuable comparison entitled "Stuffing-box for Refinery Pumps, Packing vs. Mechanical Seal." Unfortunately, two of his illustrations lacked proper clarifying notations, but his remarks are worthy of more widespread publication.

It is important, however, to re-emphasize a distinction between single mechanical seals and double seals. This difference is not sufficiently appreciated by refinery men even yet. Double seals necessitate provision of a continuous supply of seal oil in the packing box under sufficient pressure to keep the inner seal closed. Single seals either need no seal oil, or else use but a few drops per minute dead-ended to the seal faces through a passage in the stationary outer plate. There has been so much discussion devoted to double seals, their limitations, and the elaborate arrangements of auxiliary equipment required to insure their functioning, that the improvement of single seals has been largely overlooked. For many applications, where corrosive liquids are not involved, the single seals are superior to double seals as well as superior to packing. It must be remembered that the use of double seals is only one of the possible solutions to a packing-box problem.

Recommendations for Light Hydrocarbon Pumps

Single mechanical seals are recommended as the best solution to the packing-box problem for the majority of the pumps in the fractionation section of alkylation units. For the two or three pumps in this section which have the higher temperatures, single seals could also be used instead of packing if desired. To do this, a small side stream should be taken from the pump discharge, piped through a small cooler and filter, and connected into the packing box, whence it will flow back into the pump past the throat bushing, thus keeping the seal cool.

Single seals were not trusted for these light hydrocarbon pumps in any refinery units until about two years ago, except on low-pressure pumps. Until then it was generally argued that single seals were not as safe as double seals, due to the fact that any excessive leakage from a single seal might fill the pump room with gas, whereas leakage from a pump having a double seal would be absorbed in seal oil passing through the packing box. It was also felt that lubrication of single seals was difficult, making for uncertain length of life compared to double seals which are automatically lubricated by the seal oil which maintains their closure.

That reasoning, on both safety and lubrication, is now considered fallacious. In the first place the outer seal plates on single seals have been redesigned to prevent escape of any large quantities of gases in the pump house, and secondly, means have been found to lubricate single seals satisfactorily.

Incidentally, double seals are not exempt from criticism on the safety "angle" themselves, because leakage into the seal oil may be so great as to release dangerous quantities of inflammable gas in the locality where disengaging takes place, in or near the seal oil reservoir which may not be properly vented. Granted that the reliability of double seals has been greatly improved by the use of individual differential-pressure regulators in the seal-oil return lines, so that a change of conditions on one double seal does not affect the others, but even the regulators may fail on occasion.

Several factors make single seals the best choice for handling light hydrocarbons, except when corrosive liquids are to be handled. These are shown in Table 2.

TABLE 2

Advantages That Single Seals Give Pumps

Compared to Double Seals	Compared to Packing
1. Simplicity of the seal and the auxiliaries.	Elimination of frequent gland adjustment and repacking; seal faces seldom need replacement.
2. Freedom from contamination of liquid pumped.	Freedom from contamination of liquid pumped.
3. Much lower costs, both initial and maintenance.	Lower maintenance cost.
4. Less critical adjustment when assembling pump.	Cleaner appearance, due to elimination of smothering-water draining out of glands.

The development and experimentation which brought single seals to this point took place for the most part in the refineries rather than in manufacturer's plants. Perhaps the manufacturers envisaged too many impossibilities on paper, or perhaps their own experiments were influenced by the larger volume of equipment that could be sold in connection with double seals. At any rate, the need for simplicity spurred a number of men who worked with pumps in refineries to overcome the "impossibilities," so that when their ideas bore fruit and the knowledge spread, single seals were demanded from the manufacturers, by specifications. Some of these men who contributed much to the development of more satisfactory seals are T. E. Schley and E. R. Kehrer of Magnolia Petroleum Company at Beaumont, David A. Graham, service engineer for Ingersoll-Rand operating from Houston, J. B. Wampler at Gulf Refining Company's Port Arthur refinery, Smith C. Bean of Standard Oil Company (Indiana), E. Johnson at The Texas Company at Port Arthur, and two of Durametallic Corporation's representatives — Douglas Lewis in Newark and Allison Walker in Houston.

Sometimes a single seal has to handle a light hydrocarbon containing a trace of water. If this seal leaks, ice may form in such a manner as to increase the leakage. By heating the gland or outer seal plate with steam in such a case, this difficulty too is overcome.

Recommendations for Concentrated Acid Pumps

For the centrifugal pumps which are to handle either concentrated acids or hydrocarbons which contain a trace of acid, it is advisable and frequently essential that some flushing oil be injected into the

pump through the throat bushing to keep the acid from entering the packing box. A small amount of contamination takes place, of course, but this is seldom of any concern in the reactor section of an alkylation unit.

Corrosion thus being prevented, either packing or double seals can be used in these pumps. Single seals too, may some day be applied successfully to these acid-handling pumps, but this has not been considered advisable as yet. For during the times when an acid pump is not running, the flushing oil usually becomes dead-ended, which permits acid to mix slightly with the stagnant flushing oil at the throat bushing. If the pump has packing, the innermost ring should be of a material able to resist the corrosion that would then occur. Similarly, if the pump has a double seal, the innermost parts must be of materials not easily attacked by the acid. But were the pump to have a single seal, then all of its parts would be in contact with acid.

In addition to the flushing-oil system with its restricting orifices, pressure regulators and seal pots, the auxiliaries for the acid-handling pumps almost invariably include either a lubricating-oil supply (for packing) or a seal-oil-circulation system (for double seals). For the latter it is important that there be a seal pot in the "control line" which serves the differential pressure regulator, to protect it from the acid.

Reciprocating pumps for pumping small quantities of concentrated acids can be specially arranged to eliminate the packing-box problem, if necessary, by placing U-tubes half filled with mercury between the cylinders and the valves. The valves then handle the acid, but the pistons or plungers and their packing boxes handle only a non-corrosive oil, indirectly pumping the acid by the surging action of the mercury in each U-tube. If any abrasive particles should be present in the acid, the number of valves should be doubled and the pairs placed in series to guard against reverse flow.

Recommendations for Reactor-circulating Pumps

Propeller-type pumps are used to circulate the mixtures of acid and hydrocarbons because the capacities are high (at least 7000 gallons per minute, usually much higher) and the differential heads are low, probably less than 50 feet in all cases. They are usually driven at relatively low speed, somewhere between 500 and 1200 revolutions per minute, by steam turbines, frequently utilizing speed-reducing gears to permit economical steam rates. Manufacturers have to consider viscosity as well as the other pumping conditions when determining the driver horsepower for these cold-acid circulating pumps, since the mixture may have a viscosity greater than that of the individual constituents.

For the packing boxes, a flushing oil is again the first requirement, to keep the acid out of the box. Iso-butane usually is chosen to flush the throat bushing, since it is available under sufficient pressure and is not a contaminator, it being one of the hydrocarbons charged into the reactor.

Double mechanical seals are recommended for the packing boxes, because with all their "trimmings and trappings" they are a lesser evil than packing is, for these pumps. Packing has been and still is being tried in some of these large cold-acid pumps with only partial success. It is necessary to adjust the pressures of the flushing oil and the seal oil used for lubrication (in lantern rings) very carefully to obtain satisfactory packing life. Also it is advisable that the pump be built with a special device to permit occasional repacking without emptying the pump of the acid mixture. To do this some means must be provided to close off tightly a clearance between the shaft and the casing, the joint being located in the vicinity of the throat bushing.

Using double seals, it is of course necessary to supply a seal oil circulating system, preferably one system for each propeller pump, complete with automatic pressure regulation. The initial cost of the double seal probably is raised, due to the large shaft diameter on such pumps, but the "rubbing speed" of the seal faces will not be excessive since the low speed of rotation compensates for the increased diameter.

An internal bearing usually is required on such propeller pumps, and this must be lubricated from the outside. If this bearing should be placed in the packing box, between the seals of a double seal as is done on Stratford "contactors," then the lubrication of the bearing and the closure of the seals can both be accomplished by the seal-oil circulation.

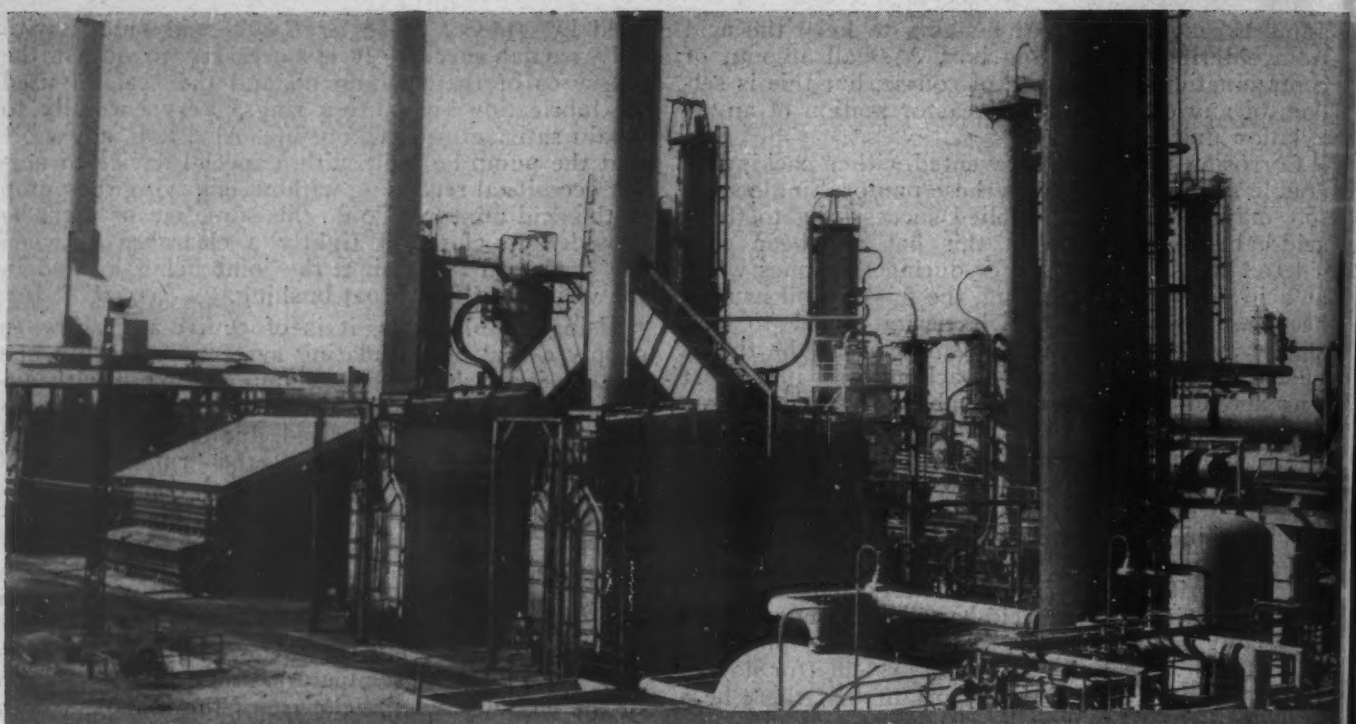
The comment usually applied to double seals by operators is included here to summarize this third recommendation, namely, "Double seals can be a pain in the neck during initial operation, but once properly set they are fine."

Conclusions

The packing-box problem has provoked refinery engineers and operators for some time, but perhaps never so insistently as during the building of alkylation units, feed preparation units, and their cousins, the butadiene plants. So that now the lowly packing box is treated with more respect. To bring about better understandings during conversation and correspondence relating to the problem, it is important that the nomenclature be free from ambiguity. Thus it helps when refinery men distinguish between such terms as flushing oil and seal oil, between single seals and double seals, between light-hydrocarbon pumps and other refinery pumps, or between dead-ending and circulating as applied to seal oil and gland oil. Incidentally, this term "gland oil" is in need of better definition, so it is suggested that henceforth "gland oil" be used to denote oil fed to a lantern ring of a packed packing box.

The applications for which double mechanical seals are well-suited are becoming limited to the pumps which handle corrosive liquids. Single mechanical seals, on the other hand, probably will find wider and wider use. Their day has already dawned in England too. F. Porges, chief engineer of a solvent refining plant for Manchester Oil Refinery, Ltd. writes of excellent performance by single seals which they developed over three years ago for pumps handling sulphur-dioxide and benzole.

There is even likelihood that United States refiners will replace some existing double seals or sets of packing with single seals, particularly in alkylation units.



The furnace area in the Norwalk plant of Wilshire Oil Company.

Shortening Up On Down Time

These workmen are examining a turbine head at one of the carts, which keeps tools and small parts within easy access of the cleanout crew.

WHEN the time comes around for cleaning the tubes of the cracking-still furnaces in the Norwalk plant of Wilshire Oil Company, F. L. McGee, the maintenance foreman, takes over and the task of allowing the least possible time between shutting down and starting up is his responsibility. Over the six years this company has operated this 20,000-barrel cracking, reforming and topping plant, the number of plug leaks encountered when testing after a clean out has been trivial. Behind all of this is a system which involves assigning men to detailed duties, and special equipment.

By having one man in charge there is little chance for confusion as to duties. With special equipment, men can accomplish more work with less exertion and be sure of returning each part to its proper place.

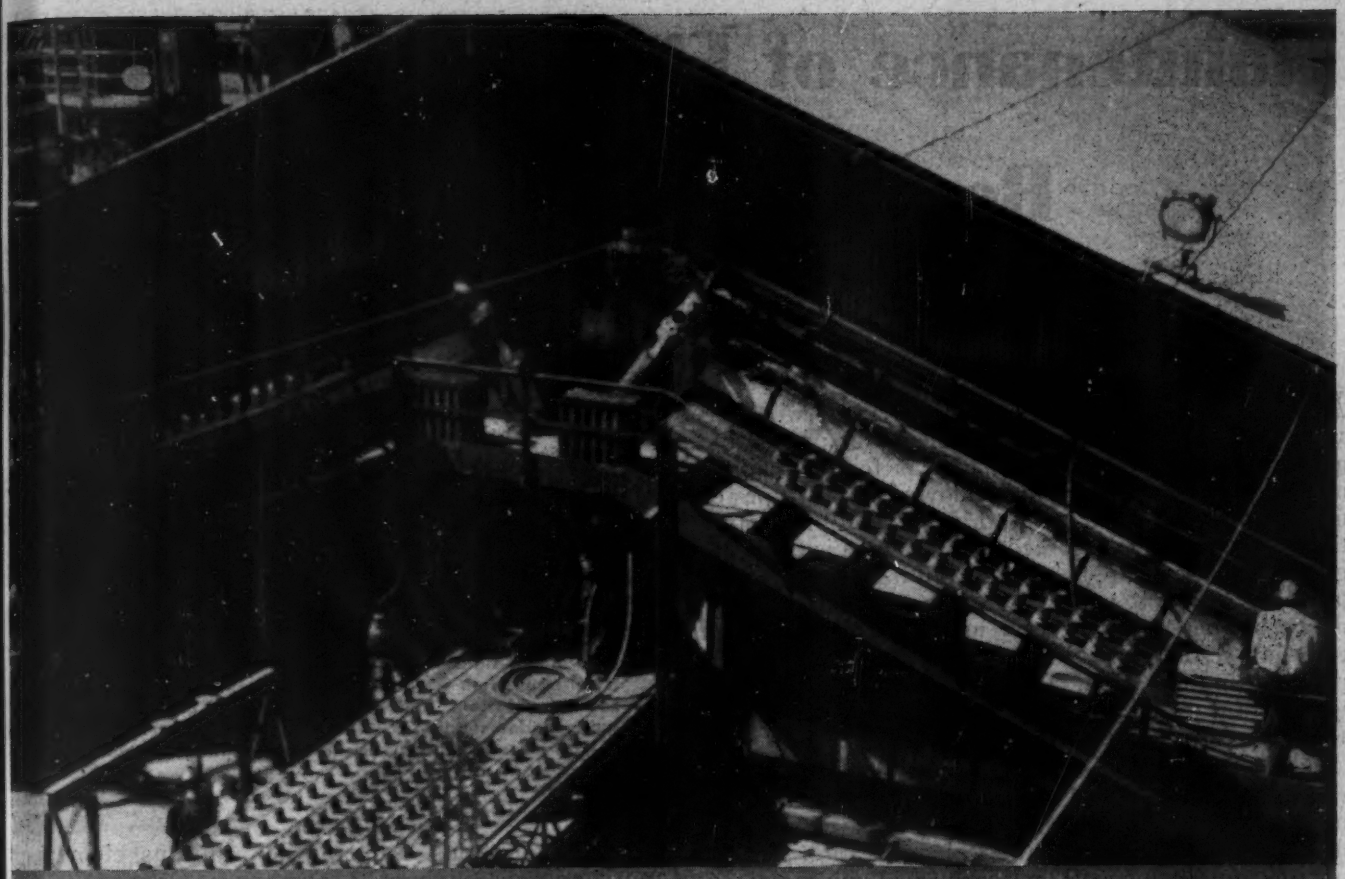
Getting each cap back into the tube header from which it was taken is considered the first requirement in avoiding leaks on cold test in the system worked out at the Norwalk plant. This is accomplished by provision of special racks, whose beds are bored and numbered to correspond with tube headers.

These collapsible racks have been built for each furnace. The frames and legs are from angle iron, while the beds are 2 x 12 timbers, into which holes have been bored. When a cap is removed it goes immediately to a hole numbered to match the header from which it came. The cap remains at this spot until it is returned to its header.

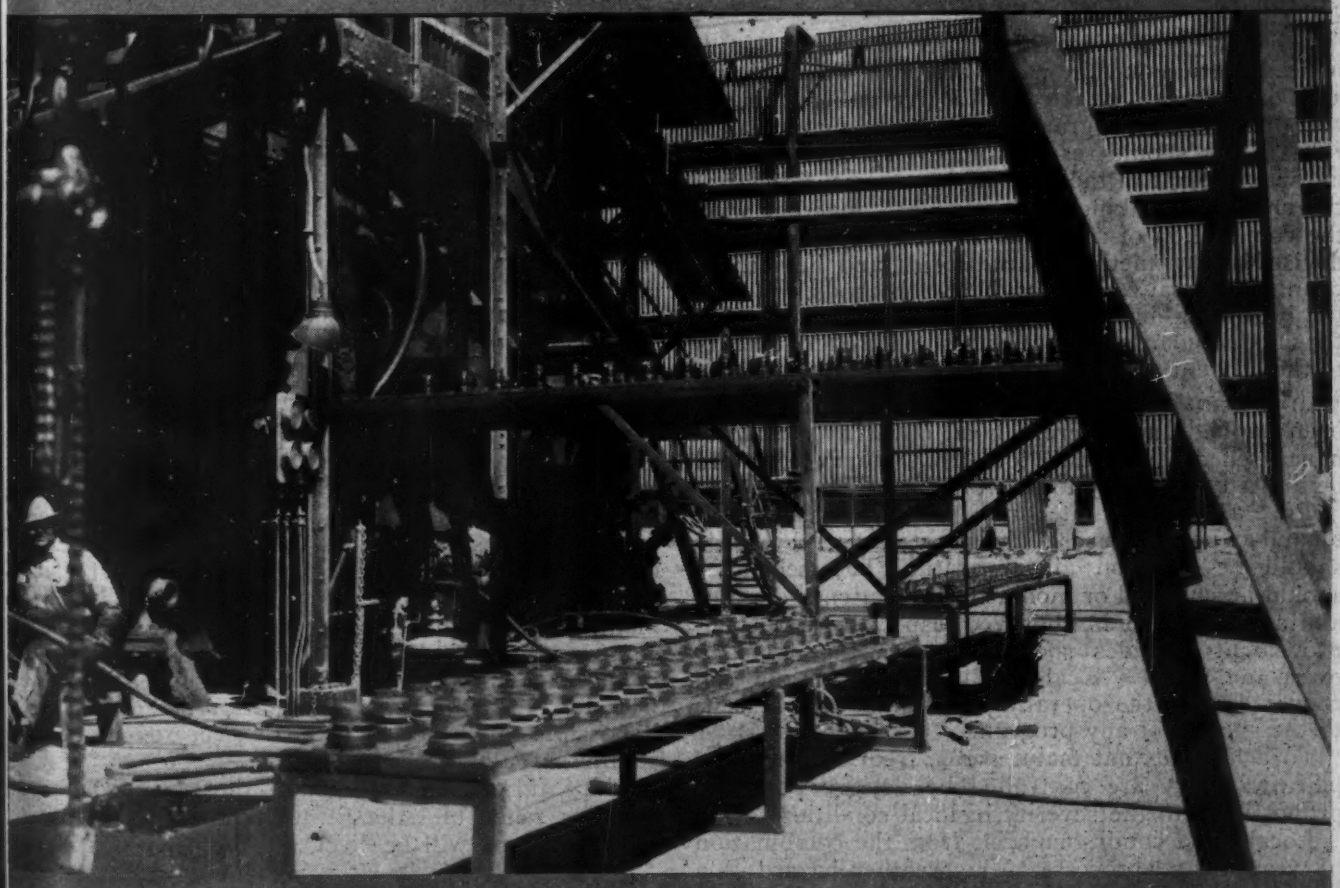
Coke burning and brushing are done while the caps are thus placed. Graphite compound is applied and the cap is ready for its return to duty.

Experience in this plant has been that even caps originally ground to precision-fit for headers will assume shapes and characteristics that dictate matching the reassembly with removal of the caps.

Portable tool carts are distributed over the furnace area in preparation for the cleanout. These contain small parts for the turbines, wrenches and the tools commonly needed for servicing the equipment. Each cart has a small vise clamped on the edge of the body.



The larger furnaces have platforms built to fit into header arrangement. This permits caps to be placed in corresponding numbered spots with a minimum of time and effort on the part of the cleanout crew.



The ground level platforms for caps from the floor tube headers show the advantage of placing caps near each other. This permits coke burners to work with little walking. The saving in time and distance carries through for wire brushing and application of compound before the caps are returned to service.

Maintenance of Electric Equipment Begins With Design

RAYBURN M. HAMILTON, Electrical Engineer, Houston, Texas

ALL maintenance can be divided into two divisions, one, repair maintenance, the other preventive maintenance. Repair maintenance is forced maintenance, necessitated by breakdown. This type of maintenance is costly in shutdown or non-productive time. The amount of forced maintenance is, in a degree, an index of the success or failure of any plant's preventive - maintenance schedule. Repair - maintenance frequency can be very useful data from which to organize or revise the preventive program after a plant is in operation. This data can be used as a guide in future installations because preventive maintenance really begins with design.

Numerous pamphlets, books and articles have been written on operational preventive maintenance, but unfortunately, most of these have treated of only maintenance after the plant is in operation and do not, except in a small measure, deal with maintenance as a factor in design. Most of them cover general conditions for all areas rather than specific conditions.

The many variables which enter into any maintenance program and the wide variety of plants in any area discourage any attempt to give either a ready-cut operational program or a design-maintenance rule. Either should result from careful study of the individual plant in the light of experience. For years the engineers making design layouts, together with the cooperation of a number of manufacturers, have devised many methods, accessories and devices to counteract local conditions. These methods, crude in the beginning, have been constantly improved. Now they are standards in most plants and are monuments to the diligent research of many men in the industry.

In a plant where proper design-maintenance has been applied and where a good operational-maintenance schedule prevails, forced maintenance should be limited practically to unavoidable accidents.

Once a design-maintenance standard has been set up and an operation schedule is in use, careful records should be kept on all apparatus. The schedules should be changed or modified as experience dictates and as equipment is improved, especially if the improvement provides special features that tend to overcome adverse local conditions. Close and full cooperation of the operating personnel is necessary to the success of any program.

To a large extent maintenance frequency and repair frequency are controlled by design. Both are proportional to the severity of local conditions.

Local plant conditions arise from the combination of weather and processes. The weather hazard — a combination of excessive moisture and heat — is beyond control and often defies prediction.

Process hazards are determined by the extent of refining operations. Among the injurious elements and conditions commonly found are:

1. Excessive heat from process operations.
2. Abrasive dusts.
3. Conductive dusts and fumes.
4. Corrosive gases and fumes.
5. Mechanical injuries.
6. Stray oil.

Other hazards resulting from design, growth, operation, or a combination of these are:

1. Improper voltage.
2. Faulty lubrication.
3. Poor plant layout.
4. Inadequate fault protection.

Design and operational maintenance are nothing more than a systematic organized fight against the industrial enemies of electric apparatus.

Some of these elements are present in every plant and some plants are a host to all of them. In some cases these injurious elements are beyond proper control or the full control is too expensive except where control is necessary to satisfactory system operation. In all cases there are methods and means of increasing the life of electrical apparatus as well as lowering the maintenance frequency. Unless precautions are given consideration in selecting equipment, the operation-maintenance program is afflicted from the beginning with ills. In some cases these ills are economically impossible to cure or, at the most, very expensive to counteract later.

The injurious effect, some of the recognized precautions taken and the future trend in combatting these elements will be discussed for each hazard.

Excessive Moisture

Condensation from excessive moisture in the atmosphere is undoubtedly the number one industrial

EXPERIENCE in designing electrical installations in the Gulf Coast is the background for this article. While the climatic conditions of this area are not typical of all refining centers, there are some with heat and humidity conditions so nearly identical that recommendations here presented will apply uniformly. Where weather conditions are more favorable the engineer can make required allowances.

The author holds to the conviction that the most advantageous time for providing for maintenance of electrical equipment is when a plant is being designed. His recommendations and observations are offered as a guide under conditions with which he is most familiar. It is the duty of the reader to fit them into his requirements.—*The Editor.*

enemy of electric equipment in areas of high humidity. It has the faculty of reducing dielectric strength of insulation to zero. In rotary equipment it is next to impossible to exclude it. It deserves number one tile, not only from its own destructiveness, but also from its willingness to aid other enemies. It provides transportation for any harmful mineral salt or corrosive gas it can dissolve. Where it cannot be excluded the best alternative is to provide a free and continuous path for its exit.

Precaution against moisture will be divided between those used on static apparatus and those used on rotary equipment.

On static equipment, the following have been used and most of them can be obtained as standard manufactured items:

1. The use of inert gas cushions under slight pressure to fill the voids in and around insulation. This method is used by electrical manufacturers to ship equipment that is to be filled with oil after installation. In plant use, this necessitates positive seals on all outgoing connections. Seals that are available include flange potheads, conduit seals and squeeze type cable seals. Sealing material for conduit seals should be water resistant and must have a coefficient of expansion near that of the conduit material to prevent leakage. Drains must be provided in the conduit if there is any likelihood of a water head being formed in the conduit above the seal.

2. The use of inert gas as a cushion above oil-filled apparatus to prevent breathing.

3. The use of conservators designed to prevent any contact between the oil and air. Methods three and four are used universally to prevent oxidation of the oil. This results in the breakdown of the oil into fatty acids and sludge which is also undesirable and detrimental to insulation.

4. The utilization of space heaters in enclosures to prevent the entrained air from reaching the dew point. Usually considerable heat is given off by the electrical equipment when energized. It seems logical that the heaters should be in two sets—one to be energized all the time, the other to operate from a thermostat or from an undervoltage relay or some convenient normally closed contacts of the device. The latter set should make up for the heat furnished by the electrical losses of the equipment when energized. The wide range of temperature is another factor. In the majority of the Gulf Coast area, for instance, this temperature difference ranges from 20° F. to 100° F. As to application, the writer has noticed a wide difference in opinion on the size of heaters among two divisions of the same large manufacturer. This difference was neither verbal nor written opinion, but was reflected in actual design. However, once you begin computations, with the necessary assumptions that must be made, this is readily understandable.

5. For many applications, totally enclosed housings are used with the equipment oil immersed. All entrances should be sealed and drains provided. Special drains are available with the drain path of extra long threads and are adaptable to explosion-proof apparatus. They are for manual operation and require a definite maintenance schedule which should vary with the frequency of humid conditions.

6. The ultimate of any method is the complete air conditioning of the area where the equipment is located. Air conditioning includes the removal of all injurious elements in the air. This is expensive and is seldom resorted to unless the equipment is of such a type that proper operation cannot be had otherwise. Such types of apparatus include electronic and precision equipment.

On rotary equipment the problem is more complicated. This is due to the impossibility of obtaining a positive seal around the bearings and to other structural difficulties, or lack of equipment to apply methods applicable to static equipment.

Some of the precautions to be taken to avoid moisture in rotary equipment are:

1. The general trend seems to be toward totally enclosed fan-cooled motors. The accumulation of moisture in the interiors of motors of this type depends on the amount of moisture in the air and the duty cycle of the motor. The leakage of air past the bearing depends on the differential of pressure. This pressure difference is created by temperature changes within the motor. Operating personnel soon recognized the need for drains in the motor frame to remove condensation. Some of these drains consisted of tapped holes with pipe plugs for frequent manual draining. Others substituted a U-shaped ⅛-inch tube. This tube provided a water seal. It was soon realized, that due to the small opening that the partial vacuum in the inside would prevent satisfactory draining. Some type of vent or vacuum breaker would be necessary to satisfactory operation. Today, vents or breathers and drains can be had as a standard manufactured item. These are suitable on explosion-proof equipment when properly installed. Under very corrosive conditions automatic drains must have frequent attention.

2. Space heaters have been and are used on rotary apparatus. Their application is more exacting than within static equipment enclosures. First, the heat must be properly distributed. Secondly, space limitations within a motor frame make it difficult to eliminate hot spot. As a general rule, space heaters are energized from normally closed auxiliary contacts of the motor controller or by relay automatically when the motor is at rest. Space heaters generally are supplied from the lighting source, at 110 to 120 volts, because this source is available during power shutdowns for repairs. Space heaters are not usually provided on motors of lower operating voltage than 2300 volts.

3. Low-voltage heating is used on motors of lower than 2300 volts rating. This is accomplished by applying directly to the motor winding a voltage that will produce heat (current) to keep air in the motor enclosure above the dew point. This method provides well distributed heat. Its disadvantage is the cost of the low-voltage transformer and the control equipment when used on motors of more than 600 volts rating. On 2300-volt and higher voltage installation, the heating-control contactor must be of the same voltage rating as the main contactor.

4. Use of forced-ventilated motor enclosures with the addition of an air dryer and/or filters has been resorted to in some cases where protection from several elements other than moisture is necessary. This procedure is expensive but exceedingly satisfactory when economically feasible.

5. Complete air conditioning of the area or building where the equipment is located, as discussed above for static equipment.

The rank or rating of the other enemies depends

on the type, location and general layout of any plant and will be taken in the order listed.

Heat

Normal weather is an enemy but one that is easily guarded against. It is ambient temperature when it has combined its efforts with process or man-made heat. Therefore, we recognized it with its full title and consider the effect of both process and weather temperature on electrical apparatus. When summer temperature of an area is high, the ambient temperature that should be used in rating equipment should be high. Also, careful consideration should be given to any process heat that might raise the normal maximum temperature of the air surrounding any equipment. Excessive heat is very detrimental to any electrical insulation. This heat may be only a few degrees over the range the machine was designed to stand, but this overheating saps the full life of the insulation. All electric apparatus emits heat. This heat is proportional to the load on the equipment. The only outlet for this heat is by convection and radiation into the surrounding air (except on specially liquid-cooled apparatus). In some exceptionally dusty and dirty location, special cooling is necessary due to the (heat) insulating effect of the dust blanket. The ambient temperature determines the rate of cooling. When apparatus is placed in abnormally high ambient temperatures some provision should be made to supply extra cooling. Forced ventilated and liquid-heat-exchanger-cooled equipment is available for special applications.

The usual method of protecting motors from excess heat, due to load, is by overload relays in the controller. Controllers can be had in more than ten different standard cases. Elements for these relays must be selected not only by the motor full-load-current rating, but also to suit the type of enclosure in which they are located. The elements must be subject to the same ambient as the motor they protect or some compensation should be made for satisfactory operation.

Other types of heat protection relays that can be used measure the total heat of the winding, regardless of the source or sources. For small motors and equipment there is the disc type bithermal relay that can be located in the winding. For larger motors and expensive equipment there are Wheatstone bridge type relays utilizing searching coils imbedded in the windings. These two types of relays are especially useful in electrical applications where the equipment may be subject to excessive process heat.

Dusts

Dust is also a destructive enemy in some plants. Dust can be abrasive, explosive or conductive. Abrasive dusts cause excessive wearing of bearings. Present day bearings are much improved over the older types used on electric rotary machines. The new sealed type bearing gives good service under adverse dust conditions. Insulation can be protected by dust-tight housings. Where abrasive and/or conductive dusts are liable to injure the glaze on insulators, armored cable with enclosed bushing pothead for terminals can be used. Some dusts are not conductive when dry. Humid climate makes dry dust the exception. Fully enclosing all leakage distances of insulator is a sure precaution. However, frequent cleaning and the use of high rating on insulator is standard with one plant where conductive process dusts are plentiful. Below is an example of the over insulation used:

Service Voltage	Insulator Rated Voltage
440 volts	7,500 volts
2,300 volts	15,000 volts
15,000 volts	34,500 volts

Corrosive Fumes and Gases

Corrosive fumes and gases in refineries do more dollar damage than other hazard and are the most difficult to overcome. These plants submit electrical equipment to the most adverse operating conditions. Nearly all types of acids and alkalies are present in varying concentrations. Heat and moisture provide an excellent carrier for these injurious elements. They are not only detrimental to all insulations, with the possible exception of glass, but are destructive to practically all enclosures except special alloys and some plastics.

Some of the measures taken to overcome corrosion, etc., are:

1. Selection of alloys or plastics that are highly resistant to the elements present for all parts for which these materials are suitable.
2. Use of protective coatings and plastic coverings where alloys or plastics are not suitable or too expensive.
3. Sandblasting of metal surfaces prior to applying protective coatings to insure a permanent bond.
4. Requiring extra dipping and a final oil-proof sealing coat baked on all insulation.
5. Use of cast iron enclosures, relying on the thickness of the metal to give sufficient life when protected with chemical-resisting paint.
6. Use of totally enclosed fan-cooled motors with special alloy or plastic fans.
7. Special ventilation of the location of the apparatus. This is sometimes accomplished by drawing air from a high stack when air at that level is free from the elements present at ground level.

Mechanical Injury

Mechanical injury is to be considered and guarded against in any plant. Naturally, the best precaution is to locate equipment so that it will be least subject to injury from operations. Some plants use crawler cranes and other heavy equipment in regular maintenance or charging schedules. Maximum clearances for the use of these types of mobile equipment should be determined and provided prior to equipment and distribution system layouts. This precaution also provides safety for workmen. Due to severe conditions in steel mills, electric equipment built especially for steel plants has been called mill type. The use of mill type equipment is justified in many cases.

Seldom in design can the danger from stray oil be determined. Oil is a solvent and will dissolve most insulating varnishes and compounds. The proper protection is usually in the selection of locations and enclosures.

Improper Voltage

Improper voltage is an enemy not present in good design. On new installations, this can be easily be eliminated by the proper selection of load centers, wire and cable sizes. The reduction in cost of a network system adaptable to industrial plants and the new

load-center equipment available has facilitated proper distribution in plants. These have minimized the low- and high-voltage problems. When apparatus is subjected to higher voltage than it is designed to withstand, the insulation is stressed. Low voltage results in the apparatus requiring more current. At full load, this extra current will cause overheating and damage to insulation from heat.

Even with excellent original design, rapid plant growth and constant process changes may produce some very undesirable and serious conditions. Sometimes voltages originally selected are too low when a plant is enlarged.

A common practice is to raise the voltage by the use of transformer taps. Where the load varies and the equipment is some distance apart, complications may arise from using taps. In most instances, the voltage will be too high at near equipment and too low at distance apparatus. Even the average is not always satisfactory. The most satisfactory solution to low-voltage problems is the addition of new load centers with the redistribution of some of the present load between centers. This method has the advantage of providing some flexibility for future additions.

Improper lubrication is more of an item for operational maintenance. However, proper selection of equipment with the most adequate systems for proper lubrication under the service conditions is design maintenance. This should be carefully considered in the selection of apparatus.

Plant Layout

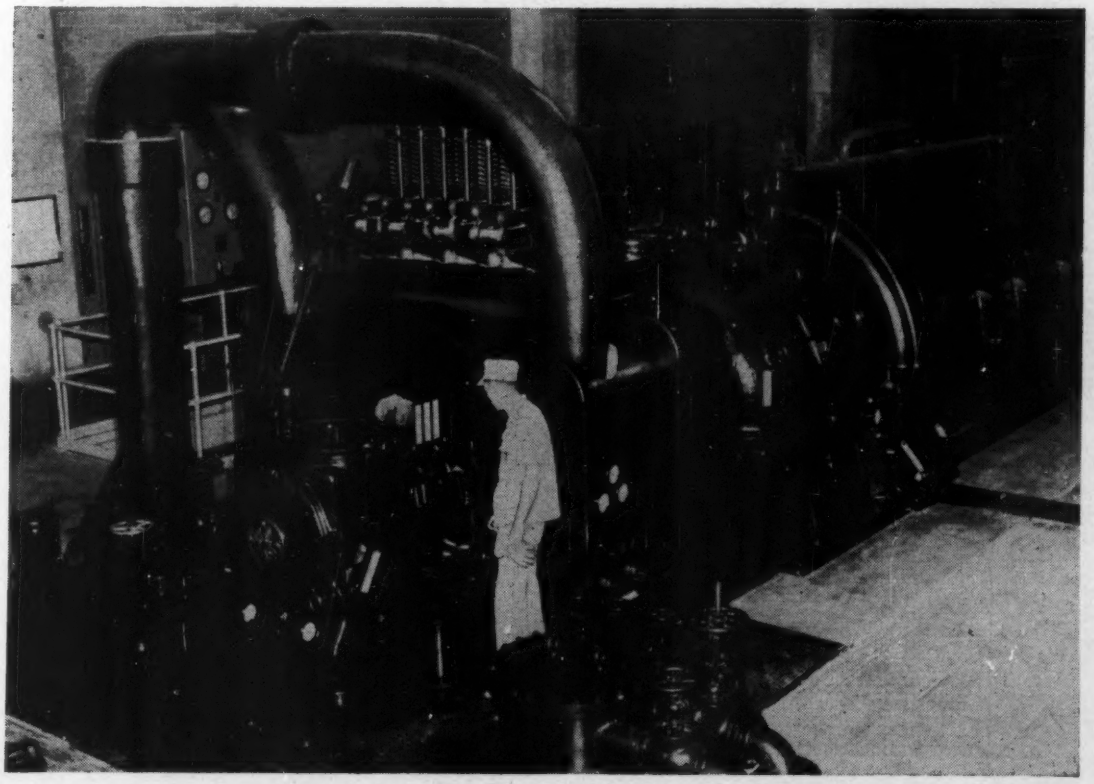
Poor plant layout is really an inexcusable man-made hazard. Except poor choice of machinery, overcrowding is, from the maintenance standpoint, the worst hazard in plant layout. All parts that need attention should be readily accessible and within general view if possible. The watch word of design maintenance is to make operational preventive maintenance easy.

Fault protection in the design of a new plant usually is or should be adequate. In proper fault protection there are three conditions to be satisfied. These are the interrupting capacity, the momentary rating and the short-time rating of the fault-clearing devices. The momentary and short-time rating of wire, when using small sizes on high-capacity systems should be checked. If faults are to be cleared quickly and with a minimum of damage to the apparatus and the circuits, all of the above ratings must be adequate to withstand maximum fault currents. Prompt and proper clearance of faults not only protects expensive equipment but also provides automatic sectionalizing and isolation of the fault area. If the plant distribution system has been properly sectionalized, faults will affect a minimum of the production capacity.

As plants, especially those with their own generating equipment, continue to grow, the more important and serious fault protection becomes. When additions are made, the whole system should be reviewed. In many cases, the interrupting capacity may be held down to the value that the existing apparatus will safely stand by using a high-reactance transformer, or by judicious use of reactors. When using reactors the load should be distributed on the buses so there is a minimum amount of current flow between buses.

Due to the haste in the war-plant building program and the substitutions that priorities imposed, many plants can profitably review their electric systems as a whole, as soon as conditions permit.

All of the above are measures to be taken in design and do not replace, but only make easier a proper and successful preventive-maintenance program.



Turbine-driven generators, Cities Service Refining Corporation, Lake Charles, Louisiana.

Construction Of Log-Log Charts

EMORY N. KEMLER, Professor of Mechanical Engineering, Purdue University

MANY types of calculations frequently can be simplified by the use of charts. Charts when properly labeled and constructed eliminate many errors which arise from the use of incorrect units. Alignment charts have been commonly used for the solution of equations. For the simpler types of equations, paralleled scales are required. There is, however, a considerable amount of numerical work involved in the construction of such charts. The use of log-log charts possesses many advantages in that they can be very easily used and simply constructed on log-log paper. This type of chart has not been treated in detail in the literature. The accuracy of either the log-log or nomographic chart is about the same as that of a slide rule having the same length of log scale. For most engineering calculations, these charts will have sufficient accuracy.

The method of construction of these charts can best be illustrated by following through a few simple examples. The charts are best adapted to calculations

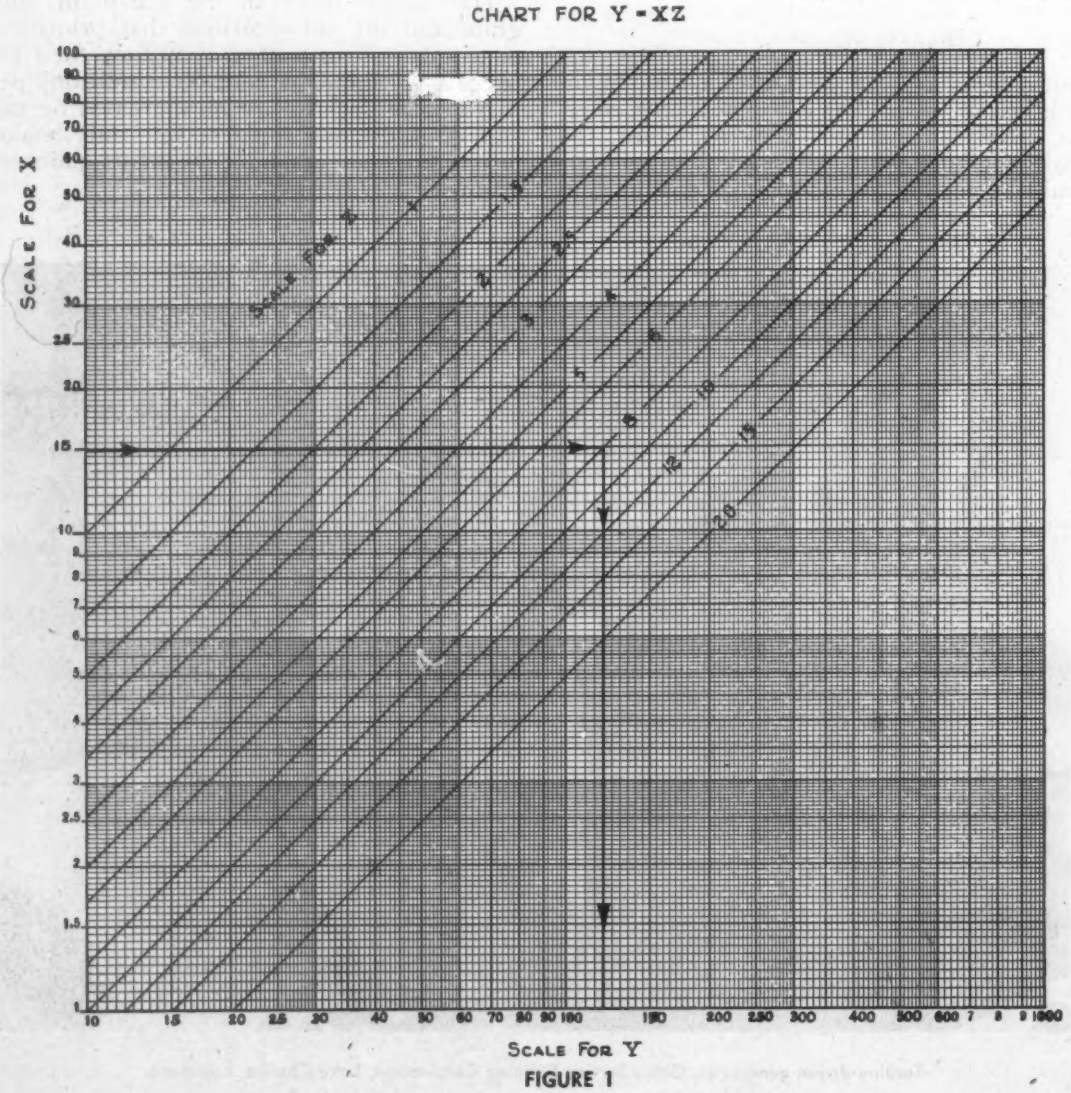


FIGURE 1

which involve multiplication of several terms which may be to any power. The simplest type of calculation is of the form

$$y = xz \qquad (1)$$

This equation can be written as

$$\log y = \log x + \log z$$

When written in this form it takes the form of the equation of a straight line except that the log is taken of each term. If this equation is plotted on log-log paper, the resulting values will appear as straight lines which will also be parallel. Figure 1 shows such a plot. The value of x is plotted on the right-hand scale. The values of z are plotted on the diagonal lines and the values of y on the lower scale. The value of y is found by tracing horizontally from the value of x to the value of z, then down to the value of y on the lower scale. The example shown in Figure 1 is to determine the value of y when $x = 15$ and $z = 8$. The arrows show the method of finding the answer which is seen to be 120. The diagonal scales of z will be straight lines at 45° with the axes when direct multiplication is involved. The effect of moving the decimal point in either the x or z scales is to move it a corresponding amount on the y scale.

Figure 2 shows a solution of the equation

$$P = .433\,SL \qquad (2)$$

P = hydrostatic pressure in pounds per sq. in.
S = specific gravity (water = 1)
L = height of fluid in feet

This equation gives the pressure exerted by a column of fluid of height L and having a specific gravity S. The solution of this equation can be made by plotting height of fluid column, L, along the lower scale and S on the diagonal scales. The plot of S will be a straight line making a 45-degree angle with the axis. Time can be saved in the construction of such charts by finding the value of L where the product of .433 L equals some multiple of 10. On such a line the pressure will be some multiple of 10 times the specific gravity. This line is denoted as x-x on Figure 2. When this line is found, the specific gravity lines can be readily drawn through the corresponding numerical values of pressures, disregarding decimal point. They will be at an angle of 45 degrees with x-x. The lines can also be drawn using a straight edge by selecting the next value of L which will make the pressure some multiple of 10 times the specific gravity and drawing the lines through corre-

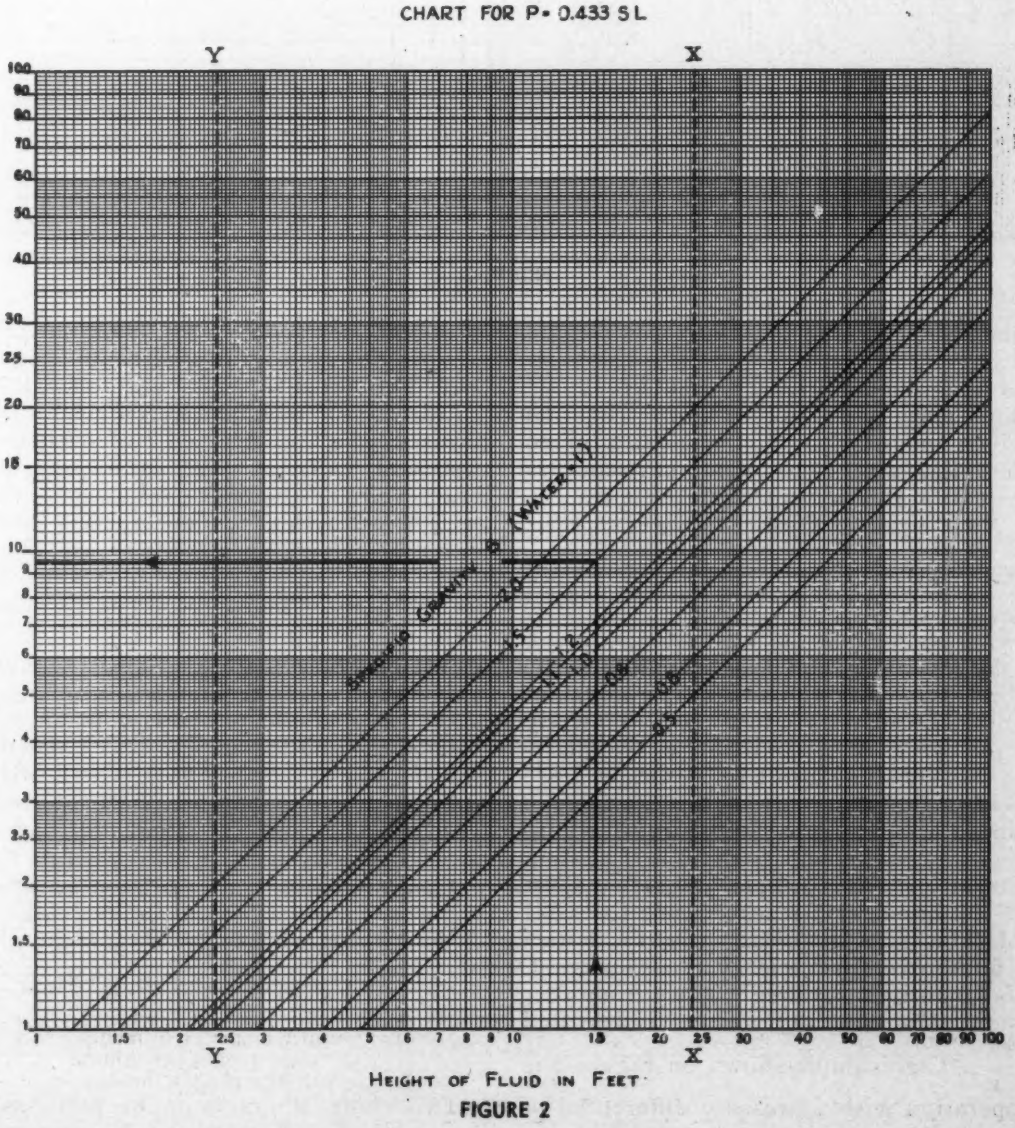


FIGURE 2

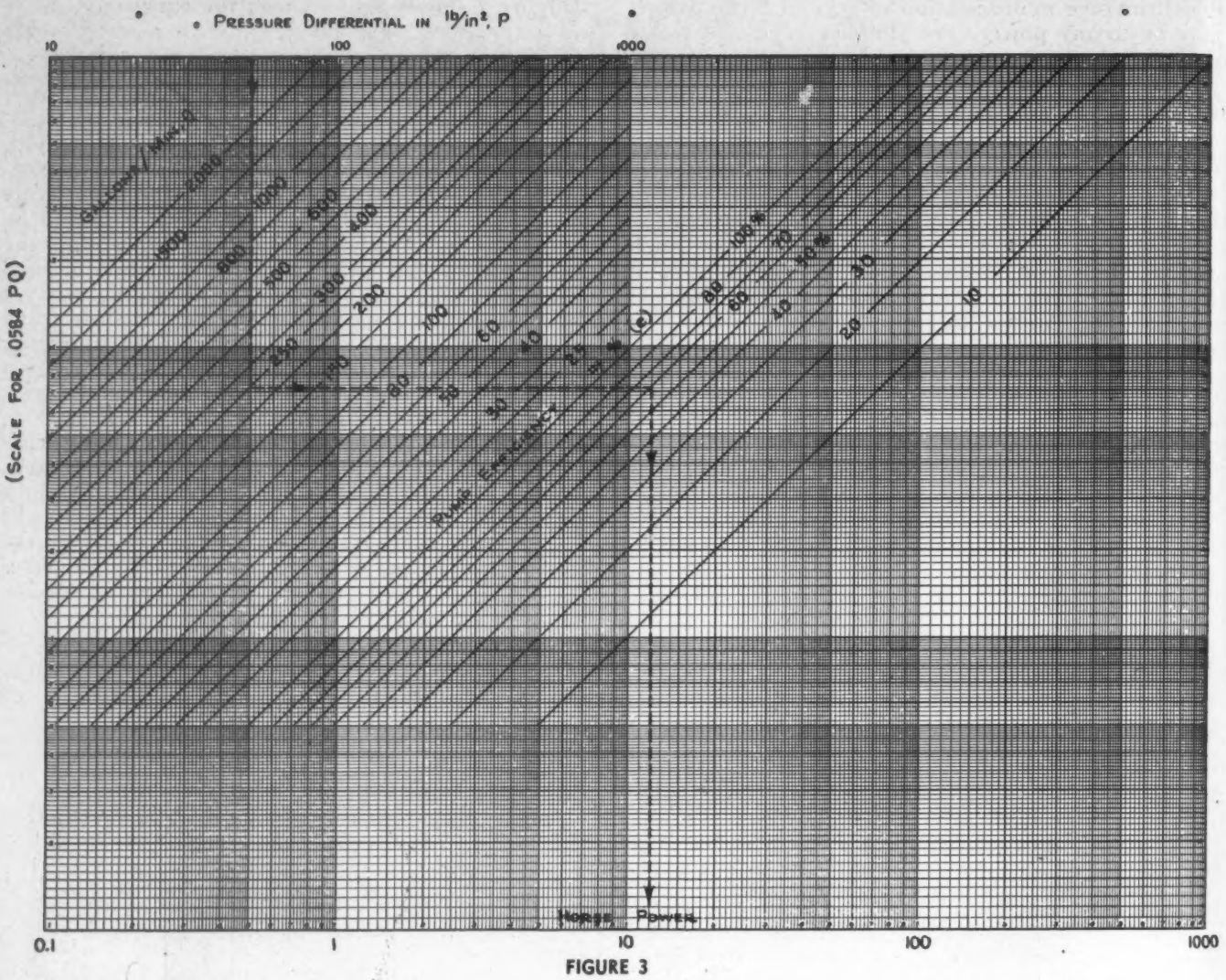


FIGURE 3

sponding values of pressure. This line is indicated by y-y.

A chart involving one additional variable is shown in Figure 3. This chart gives the horsepower required to pump a given quantity of fluid against a given pressure differential when the pump efficiency is known. The equation can be written in the form

$$HP = \frac{QP}{17.10e} = .0584\ \frac{PQ}{e}$$

where P is pressure differential in lb./in.²
Q is quantity of fluid pumped in gallons/min
e is pump efficiency in percent.

The chart can be constructed by first combining any two of the variables and then combining the product of these two with the third. The constant term can be introduced with either pair. It merely shifts one set of curves. Frequently it will be desirable to divide this constant into two factors and use each factor with a different part of the equation in order to be able to better spread the curves or conserve space. Figure 3 was constructed by first making the multiplication .0584 PQ. These values could be shown on the left-hand scale marked scale for .0584 PQ if desired. This scale happens to be the horsepower if the pump overall efficiency is 100 percent. By using this quantity as though it were another variable z where $z = .0584\ PQ$ you proceed to find the value of $\frac{z}{e}$. The example shown on Figure 3 is for a pump operation with a pressure differential of 50 pounds per square inch, handling 250 gallons per minute and having an overall efficiency of 60 percent. The horsepower is seen to be 12.

Equations involving the multiplication of more terms can be constructed by continuing the above process. It will, however, require a log-log chart with more cycles. Log-log paper can be obtained in 1 x 1 cycle, 1 x 2 cycle, 2 x 2 cycle, 2 x 3 cycle, 3 x 4 cycle and 3 x 5 cycles. These sheets, available in letter and twice letter size, can be pasted together if more cycles are necessary. The resultant chart can then be photostated to the required size.

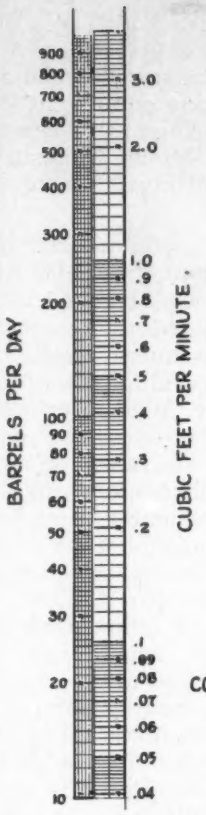
Log-log charts are also easily adaptable for use where several conversion scales are required. Figure 4 shows a simple method of making a conversion chart using log-log paper. This particular chart can be used for converting flow rates in barrels per day to cubic feet per minute. The cubic feet per minute will be 0.0039 times the barrels per day. One hundred barrels per day will be equivalent to 0.39 cubic feet per minute as can be seen from Figure 4.

Figure 5 shows a chart for calculating the volume of fluid a single-acting pump will handle per minute.

$$V = \frac{d^2}{4 \times 144} \times \frac{NL}{12} = .000455\ NL\ d^2$$

where V = cubic feet per minute
d = plunger diameter in inches
N = working strokes per minute
L = length of stroke in inches

This chart differs from the previous ones in that



CONVERSION FROM BARRELS/DAY TO CUBIC FEET/MINUTE

FIGURE 4

one of the variables, d, enters as a square. This part of the chart can be constructed by plotting d^2 values and labeling them as d values. An inspection of these lines show how they can be laid out. More complicated charts involving the multiplication of variables which can be to any power can be made up in a similar manner.

To illustrate the use of Figure 5, consider the case of a pump with a 10-inch stroke, 30 strokes per minute and a plunger diameter of 1 inch. Enter the chart on the line marked strokes/min, trace down to the length of stroke, then to the right to plunger diameter of 1 inch, then down to lower scale and read capacity of .138 cubic feet per minute.

These examples illustrate in a general way how log-log charts can be laid out on printed log-log paper with a minimum of effort. The method can be appreciated best by actually working out some examples. Some difficulty may be experienced in getting a simple chart at first. Manipulating of constants may improve the appearance and utility of such charts. In these examples some intermediate lines have been left out to permit easier following of the method.

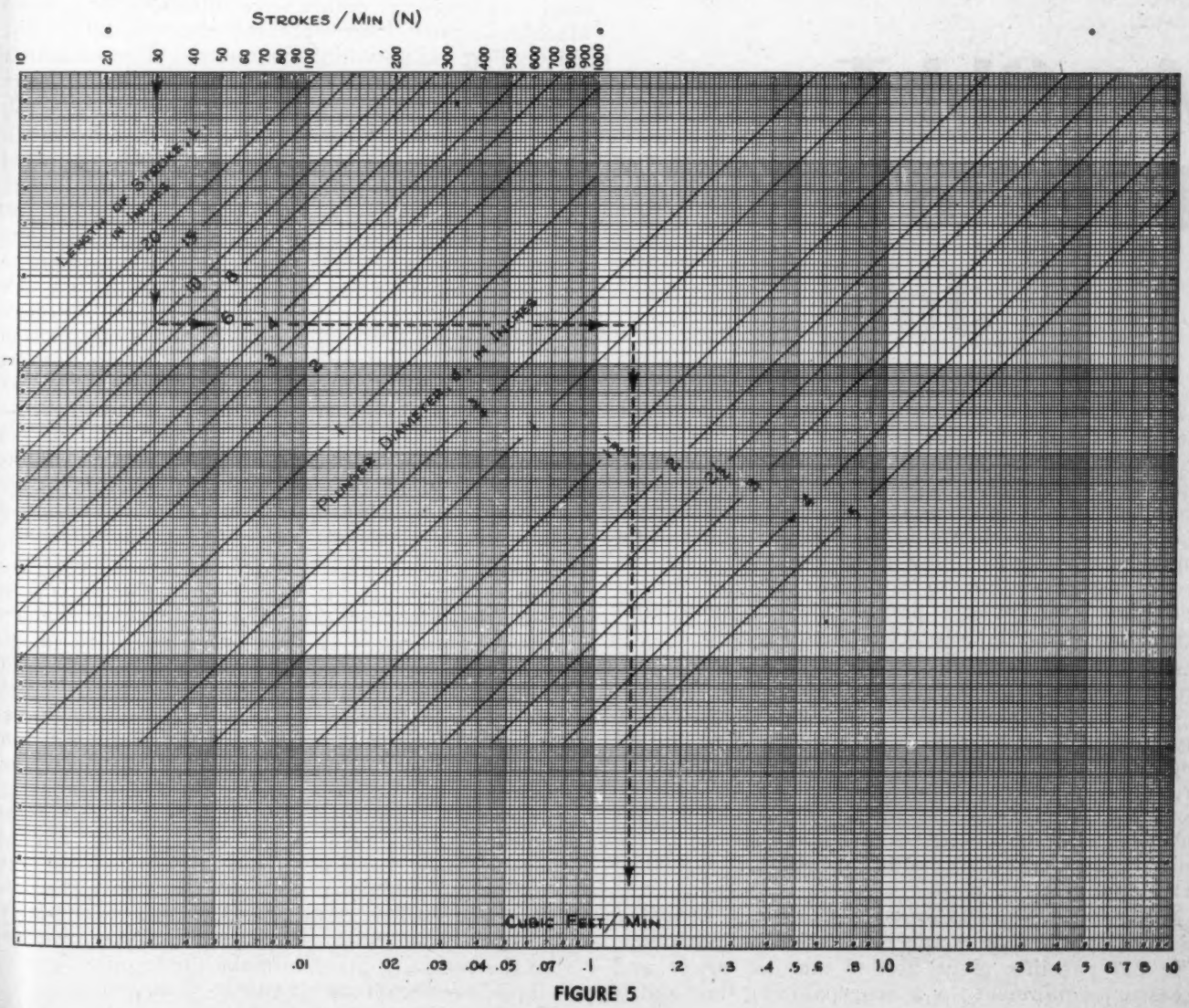
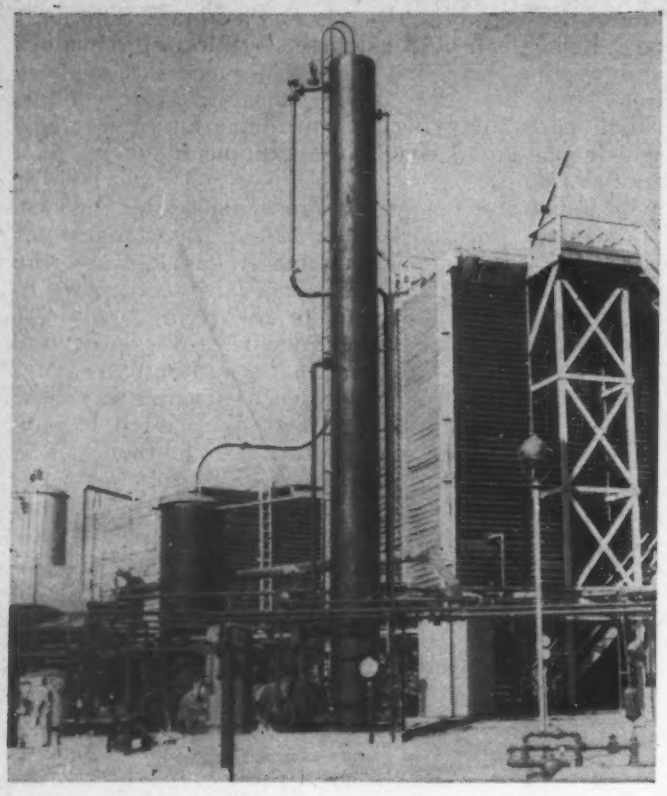


FIGURE 5



An Old Tower Goes to a New Job

INGENUITY in finding and adapting equipment rather than ingenuity in processing has become a prime requirement in areas where specialty extraction plants are being provided for using the finer "cuts" of natural-gasoline plants for 100-octane gasoline and for ingredients for synthetic rubber. The engineer who knows how to accomplish a step in processing often has to organize his staff into a searching party whose prime objective is to find equipment with which to accomplish the step.

All this had to be done in one gasoline plant in order to furnish a depropanized butane for a specialty-fractionating plant, which is a vital part of war products from petroleum. This gasoline plant had its beginning as a casinghead plant and continued to grow and improve as more was learned of fractionation. Its output was the several grades of natural gasoline with the overhead fractions reduced to required vapor pressure and converted to liquefied petroleum gas.

Market for a propane-free butane was provided with completion of a specialty-fractionating plant. The old gasoline plant needed another tower and accessory equipment for a depropanizing unit and it was no longer possible to go to a fabricator for what was needed.

Engineers started a systematic survey of the area to determine the feasibility of taking equipment from plants where conditions had so changed that removal of a vessel would not hamper operations. This survey revealed that other gasoline manufacturers were willing to aid in the program.

The survey made available a medium-sized fractionator in a plant in a rapidly depleting field. After being laid down and stripped, it was trucked to the main plant where it was scheduled to be erected. Steamed thoroughly, it was subsequently subjected to a hydrostatic test to obtain a working factor which determined its operating pressure. Well in excess of any pressure which it might be operating under when depropanizing, the column was raised on a concrete base and bolted down. Supplementary guy-lines were attached, and the column insulated after being piped for the running flow. In the absence of any new equipment, the accessories were obtained where instruments and fittings could be spared. The overhead-condensate accumulator and reflux tank was converted from a field separator which was built with an internal liquid float attached to the manhole cover. This was removed and the stuffing box packed off so it would be vapor tight. An external remote-controlled liquid valve was attached to the shell of the tank to pass the propane to storage. The pumps used for charge and reflux were rebuilt duplex piston machines which have operated successfully in the place where simplex high-volumetric, close-clearance pumps might otherwise have been installed.

The piping is a combination of welded, screwed joint and flanged, depending upon the fittings available and the kind of pipe on hand. The control panel at the side of the column contains several instruments, no two of which are of the same manufacture, some of which even are connected with controllers adapted to the job which were intended originally to be used in conjunction with other instruments. Because no liquid-level controller for the fluid outlet of the reboiler was available, one of the mechanics in the plant built a serviceable one by using a short nipple of pipe and attaching air-operated remote-control valves. This instrument maintains a predetermined level in the reboiler without material variation for days at a time, and performs as well as instruments which might have been obtainable before restrictions were placed on the manufacture of such equipment.

From a casual inspection of the stabilization, or depropanizing unit, one would guess that it was of standard construction, but when going over the setting, piece by piece, it shows the ingenuity of engineers who have the ability to build a serviceable equipment, frequently making something worth while when little is available to begin with. Operation has been as satisfactory as the building. While the composition of the feed varies as to the vapor pressure of the product leaving the main stabilizer, the amount of propane remaining in the cut of the butanes is consistently less than 1 percent. On the other hand, by careful operation, none of the isobutane is pulled over in the top vapors with the propane. Overhead is total condensation and subsequently blended with the normal butane returned from the specialty plant to make the required grades of liquefied petroleum gasses.

Application of Unit Operations To Fractionation and Other Vaporization Processes

PART 7

The Utility of Phase Diagrams

R. L. HUNTINGTON, School of Chemical Engineering, University of Oklahoma

GRAPHICAL sketches of P-V-T and vapor-liquid relationships serve as useful tools in explaining the physical and chemical laws governing the behavior of water and the petroleum hydrocarbons. These diagrams provide the engineer with a mental picture of certain principles which cannot be readily gained by other methods of instruction. An analysis of simple chemical compounds should be undertaken before the more complex relationships involving two or more components are considered. Since water is the most common fluid on the earth, a knowledge of its properties in solid, liquid, and gaseous states is essential for all engineers.

Three-Dimensional P-V-T Model for Water

1. Pressure-Volume Relationship—This graph is made by plotting isotherms (constant temperature lines) through the several phase regions, each isotherm being located in a separate (P-V) plane (Figure 1). It is difficult to present such a diagram isometrically, or in a manner which gives a third dimension depth, perpendicular to the P-V plane of the paper.

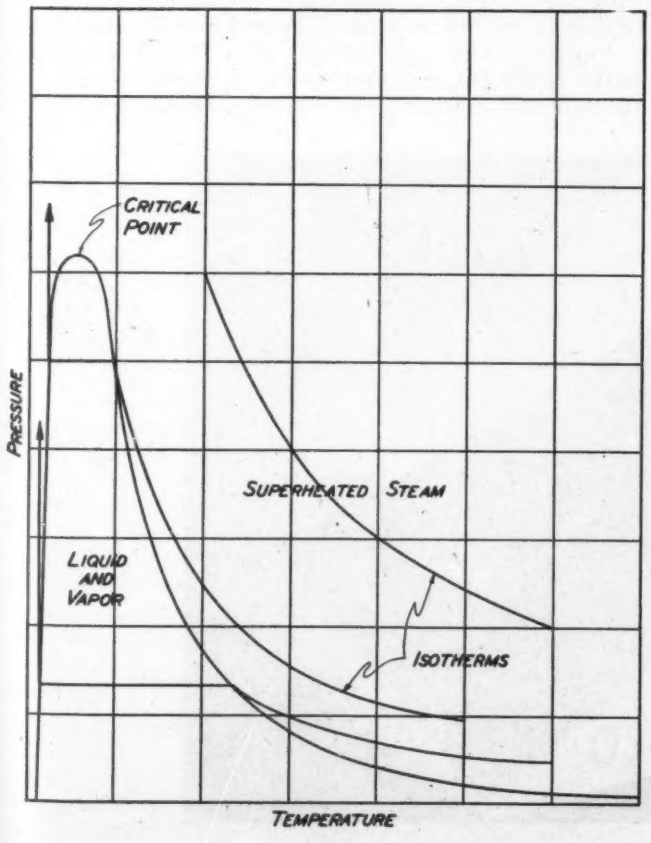


FIGURE 1
P-V isotherms for water and steam (not drawn to scale.)

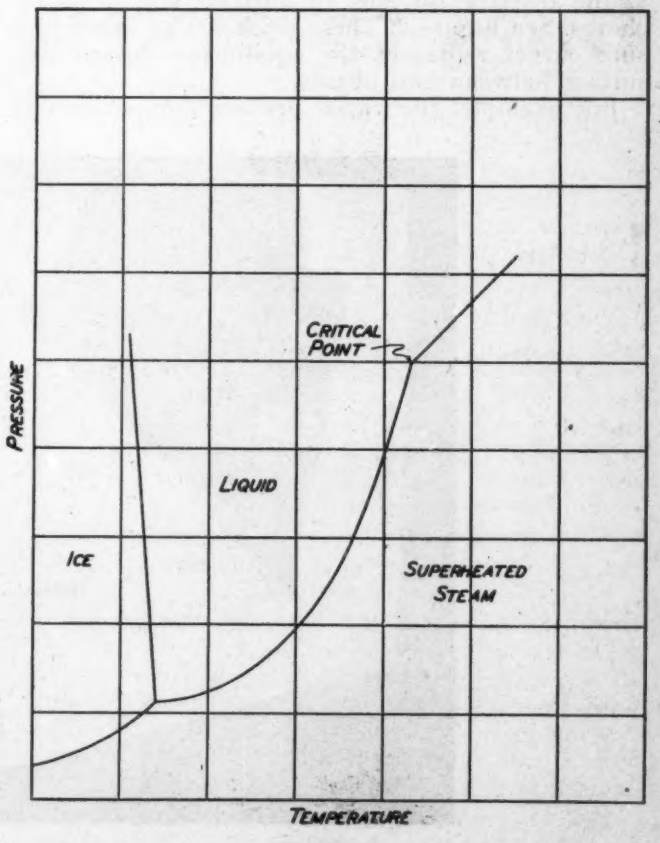


FIGURE 2
P-T isochores for ice, water and steam (not drawn to scale.)

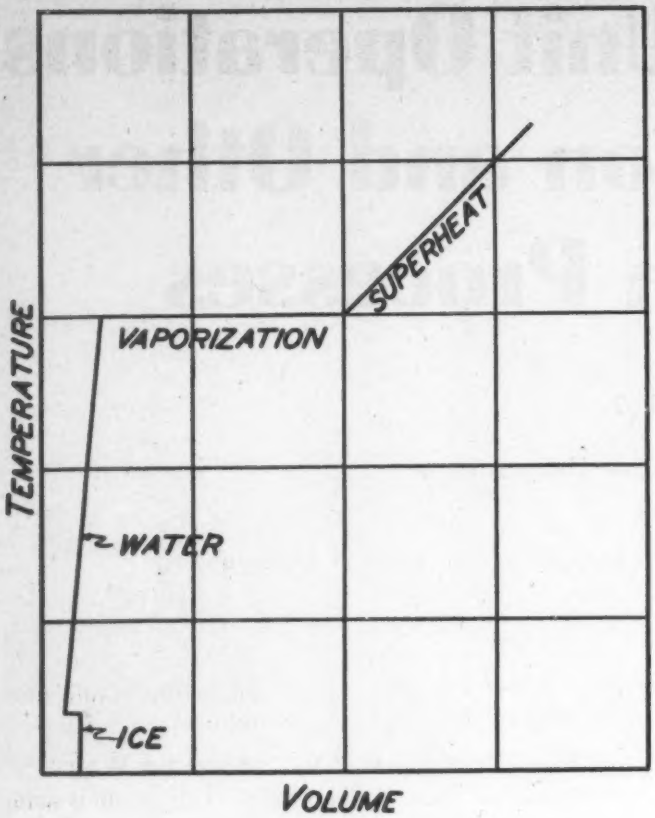


FIGURE 3
T-V isobars ice, water and steam (not drawn to scale.)

2. Vapor-Pressure or P-T Plane—The relationship between pressures and temperature is usually shown by plotting pressure as the ordinate and temperature as the abscissa, for lines of constant volume or isochores. See Figure 2. These isochores or vapor pressure curves represent the equilibrium interface or surface between two phases.

For example, the vapor pressure or sublimation curve for ice is the equilibrium line separating ice and vapor. At 32° F. this curve runs into the triple point where ice, water, and water vapor are in equilibrium at that temperature and a pressure of 0.0886 pounds per square inch, absolute. This point is sometimes called the non-variant since there are no degrees of freedom. This can be shown by the phase rule, there being three phases, which are equal in number to the one component plus two. The boundary between ice and water shows that the melting point of ice decreases with increasing pressure.

The vapor-pressure curve for water represents the boundary line between water and vapor up to the critical temperature and pressure. Above this critical point, the isochore is a straight-line relationship for a perfect gas between pressure and temperature, the absolute pressure doubling for every two-fold increase in absolute temperature. For mixtures of two or more compounds there are two critical temperatures. These phenomena will be discussed in a later paper.

3. Isobars on the T-V Plane—This view of the three-dimensional model can be gained by looking downward on it, since pressure usually is plotted as a vertical component. This relationship is used to a smaller extent in engineering work than either the P-T or P-V diagrams. Figure 3 can be better understood perhaps by picturing the flow of water as it is pumped under substantially constant pressure of 200 pounds per square inch, absolute, into a boiler, the liquid volume increasing slightly with rise in temperature until the boiling point is reached. There is then a large increase in volume at constant temperature, this being the transition or vaporization of water into saturated steam. A further increase in temperature at 200 pounds pressure will result in a substantially two-fold volume increase for every time the absolute temperature is doubled. This latter region is known as that of superheated steam.

Figure 4 is a photograph of a P-V-T plaster of paris model[2] for water in its several states. Although this model is not made to scale, it serves as

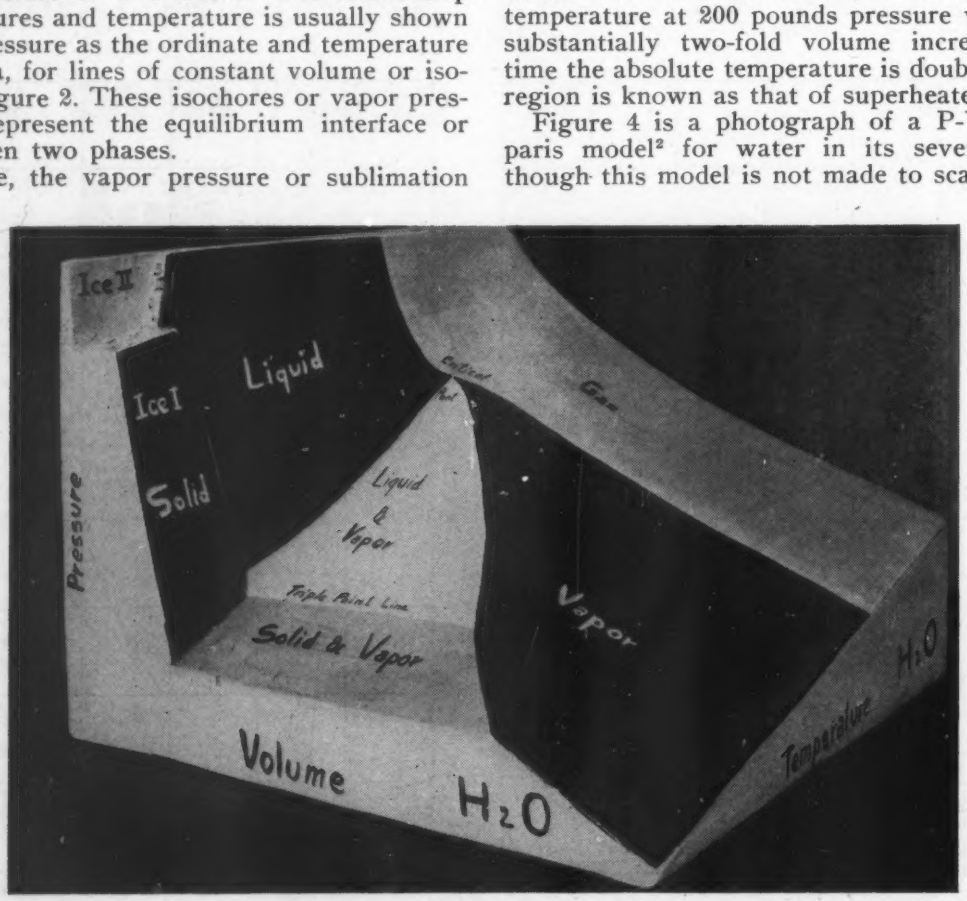


FIGURE 4
P-V-T model for H_2O (not made to scale.)

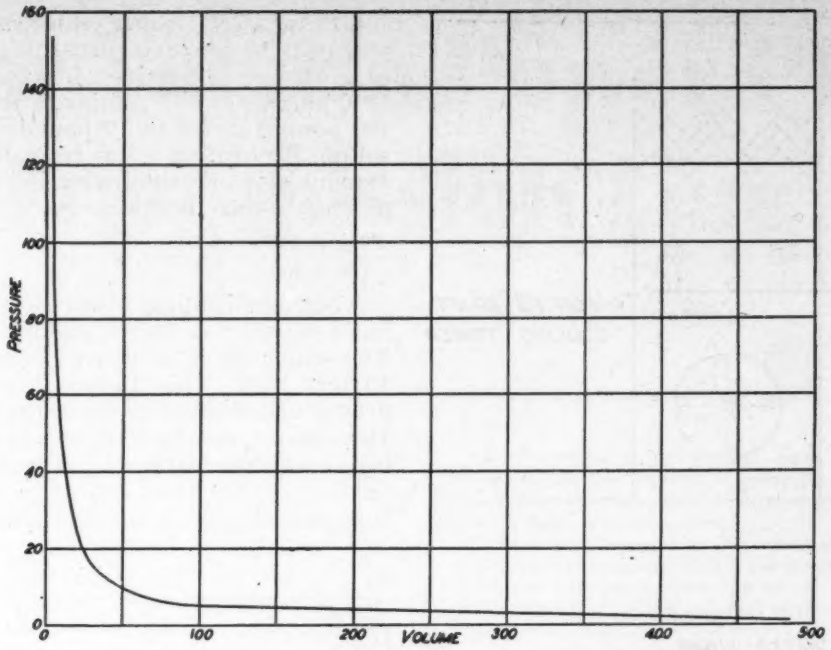


FIGURE 5

Isothermal expansion of steam at 360° F. Work performed equals area under curve between volume limits $\int PdV$.

a very useful tool in picturing these relationships in their three dimensions.

Application of the P-V Diagram to Power Generation

The petroleum engineer is interested in the available energy which may be present in a fluid such as a compressed gas or a gas-saturated liquid. The isotherm for superheated steam at 360° F. between the saturation pressure of 153 pounds per square inch, absolute, and 1 pound per square inch has been transferred from Figure 1 to Figure 5. The work which a pound of this steam will do in expansion between these two pressures at 360° F. can be determined by graphical integration or summation of the area under the curve, as shown by the shaded region. To keep the fundamental units consistent, the pressure is measured in pounds per square foot and volume in cubic feet, therefore the product or the area would be in feet. Since one pound of steam is being considered, the work done would be in feet times pounds or foot-pounds. This area happens to be 360,000 feet and the foot-pounds of work amount to $\frac{360{,}000}{33{,}000 \times 60} = 0.1815$ horsepower hours, assuming steam to be a perfect gas in this range. If this pound of steam expands through this pressure range in 1 hour's time 0.1815 horsepower will be exerted. In other words, power is the time rate of doing work.

Since the deviation or compressibility factor for steam is greater at high pressures than it is at the lower-pressure range, the pdv is greater than one would obtain by calculating the amount of work from the isothermal expansion of a perfect gas. In this case, the latter would yield foot-pounds of work or energy:

Basis 1 cubic foot of steam

$$R \times T \times 2.3 \log_{10} \frac{153.01}{1}$$

$$\frac{1544}{18} \times (460 + 360) \times 2.3(2.184) = 354{,}000 \text{ foot pounds.}$$

This quantity amounts to 6000 foot pounds or 1.67 percent less than the actual expansion of one pound of steam as obtained by graphical integration.

The Utilization of Residue Gas for Power

For a number of years, natural-gasoline plants overlooked the fact that the residue gas coming from the absorbers held within itself a vast reservoir of energy. This gas usually was brought to low pressure through reducing regulators without the recovery of any of the energy it had stored up. Today the gas-driven turbine is utilizing this expansive energy in the gas between the 50 to 60 pounds per square inch (absolute) absorber pressure, and the atmospheric exhaust pressure at which pressure level the gas can be burned as fuel. Where fuel is cheap the heating of the gas is another means of securing added power as shown by Figure 6. This practice is especially desirable for high-velocity turbines as a small amount of condensation will cause wear and "wire cutting" of the turbine blades.

Where very large volumes of excess residue gas are available, gas-water lift systems have been in-

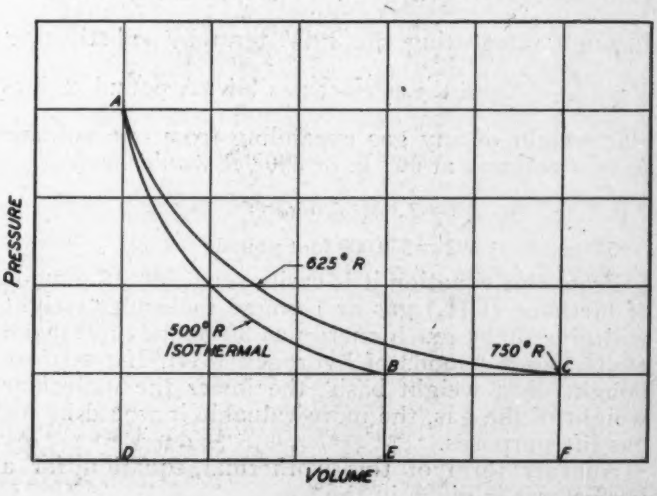


FIGURE 6

Increase in available work energy by heating during expansion.

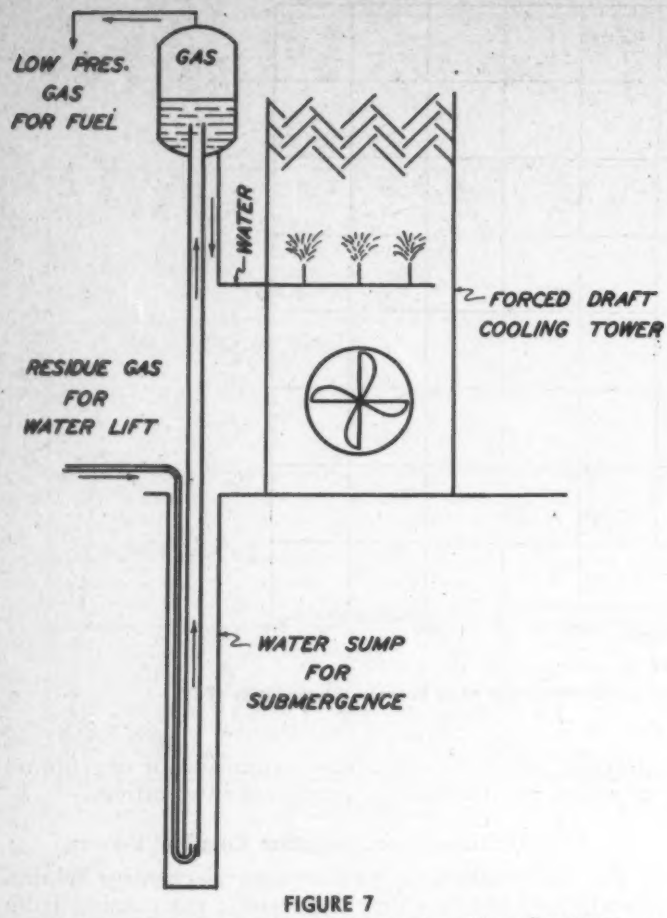


FIGURE 7

Gas-water lift system operating in conjunction with cooling tower.

stalled adjacent to water-cooling towers. Although the expansion efficiency of such a lift system may not be as high as that of a turbine, the lower initial investment makes the installation of the vertical pipes highly desirable. By referring to Figure 7 it is seen that the water submergence should be at least as much as the water head above the surface of the coil pit or "water well."

Calculation of the Efficiency of a Gas-Water Lift

For the isothermal expansion of a perfect gas the integrated value of the expansive work, $\int PdV$, is expressed as $RT1n \frac{V_2}{V_1}$. This formula is obtained through integrating the PdV term by substituting $P = \frac{RT}{V}$ from the perfect gas law. A pound molecular weight of any gas expanding from one volume to two volumes at 60° F. or 520° R would be:

$$R \times T \times 1n_e \frac{V_2}{V_1} = 2.3\ R\ T \log_{10} \frac{V_2}{V_1}$$

$$1544 \times 520 \times .692 = 550{,}000 \text{ foot pounds}$$

From this equation it is easily seen that 16 pounds of methane (CH_4) gas or 1 pound molecular weight will give up as much energy as 30 pounds of ethane (C_2H_6) or 2 pounds of hydrogen (H_2). If gas were bought on a weight basis, the lower the molecular weight of the gas, the more valuable it would be for gas-lift purposes.

Another form of this isothermal equation for a perfect gas is given in the form:

$RT\ 1n\ P_1/P_2$, since volumes are inversely proportional to absolute pressures. The same amount of work can be obtained from a gas expanding from 1000 pounds to 100 pounds as there is available from 100 pounds down to 10 pounds per square inch, absolute. By heating a gas from 100° F. to 200° F. the amount of work obtainable is increased by the ratio of the absolute temperatures.

$$\frac{200+460}{100+460} = \frac{660}{560} = 1.18$$

A certain cooling tower of the atmospheric type has a capacity of 10,000 gallons of water per minute. The water must be lifted 55 feet since the tower is 40 feet high. This 15-foot head is needed to give proper distribution to the spray nozzles and headers. How many standard cubic feet of residue gas of the following composition: Basis—100 lbs. mols

	Vol. Percent	Mol. Percent	Mols.		Lbs. Mol.		Lbs. 100 Mols.
Methane	80	80	80	x	16	=	1280
Ethane	15	15	15	x	30	=	450
Propane	5	5	5	x	44	=	220
							1950

will be required to lift the water per 24 hour day?

If the absorbers are operating under 50 pounds per square inch, absolute, and the gas-water separator at the top of the lift tower is to be 16 pounds absolute, the calculation can be made as follows, based on isothermal expansion at 60° F. or 520° F. absolute:

$2.3\ R \times T \times \log_{10} P_1/P_2$

or $2.3 \times 1544 \times 520 \times \log_{10} 50/16 = 910{,}000$ foot pounds of work per pound mol or 380 standard cubic feet of gas, one pound mol of gas would lift $\frac{910{,}000}{55} = 16{,}500$ pounds of water since each pound of water is to be elevated 55 feet. Each standard cubic foot of gas would lift $\frac{16{,}500}{380} = 43.5$ pounds of water. There are $10{,}000 \times 8.33 \times 24 \times 60 = 120{,}000{,}000$ pounds of water to be circulated per day, therefore $\frac{120{,}000{,}000}{43.5} = 2{,}760{,}000$ standard cubic feet of gas will be required per day, based on 100 percent lift efficiency.

It has been found by Cromer et al[1] that lift efficiencies for an air-water column vary from 0 to 42 percent. If the above gas lift system has an efficiency of 40 percent, the gas requirement will be $\frac{2{,}760{,}000}{0.4} = 6{,}920{,}000$ cubic feet per day. The saving in kilowat hours at 1.0 cent per KW hour will amount to:

$$\frac{120{,}000{,}000 \times 55/\text{ft. lbs.}}{33{,}000 \times 60/\text{ft.lbs./H.P.hr.} \times .8/80\%\text{ efficiency}} \times \frac{\text{K.W./H.P.}}{.746/\ \times .01} = \$31.00$$

per day savings in electrical energy.

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[1] Cromer, S. and Huntington, R. L. A.I.M.E. Petr. Tech. T.P. 1080 August, 1939.
[2] Welch Company, W. M. Chicago, Illinois.

Motor Vehicle Power Plants And Transmission Line Units

ROBERT CASS, Chief Engineer, White Motor Company

THE KIND of power used in the postwar, whether Otto cycle or diesel, bears discussion as the fuel plays only one part. In the broadest sense, we have two fuels to consider—fuel as used with the diesel cycle, and fuel as used with the gasoline engine. While butane and propane have their spot, they are not fundamental in terms of power development to the same degree as the diesel and gasoline fuels. It might be fair to say that up to date there has been no motor vehicle combination that has fully met the fundamental requirements of weight cost and per-mile expense. Engines designed for trucks will be available in the postwar with sufficient horsepower to handle high loads, and there will be both gasoline and diesel engines. It may show from our examination that the fuel situation has undergone a strange turn during this war and that unlooked-for effects are coming out of the change in technology of fuel refining. On one hand, there is the statement that the new catalytic processes mark the doom of efficient diesel operation, in the sense as we have understood it in the past, in truck transportation. On the other hand, we have the statement that octanes will be available that will make possible engines of half the size in the gasoline field to do the same amount of work. Both are possibilities, to some degree, in the immediate future and they represent challenge in both cases.

The story of prewar Europe, often cited in relation to the diesel engine, is of no value now in evaluating our future progress in this country, because, certainly, the considerations existing then are not likely to be present in our postwar. The fuel picture will be different there also.

Let us then consider the question of what may happen to diesel fuels and its effect on the overall engine picture. There seems to be no doubt that the catalytic processes, which have been initiated during the war to a greater degree than ever before, will be continued in the postwar. It is conservatively estimated that the amount of refining equipment that has been built is equal to the total amount of refining equipment available before the war. It seems obvious that the newer equipment will be used and the old equipment written off. We may then face the possibility of having the best diesel oils used in the catalytic process for manufacturing aviation gasoline and also having the catalytic-processed diesel fuel come out initially with a low cetane number for the diesel engines. This will mean doctoring the fuel with additives to improve the ignition point, and we may have the problem of engine deposits accentuated by this change in refining processes.

C. M. Larson of Sinclair Refining Company in a paper entitled "Octanes or Cetanes After World War II" is very specific:

THIS article is an extract from a paper presented before the Los Angeles Chapter of the Society of Automotive Engineers. Only that part of his paper, dealing with fuels has been used.

It is significant that the manufacturer of the diesel engine is concerned about the quality of fuel indicated for the postwar period, the refiner is concerned about the number of diesel engines that will be available for consuming fuel.

Present indications are that percentagewise the diesel power plant will make the outstanding advance as a consequence of the war requirement. Since the refining industry never has failed to provide high-quality fuel for the internal-combustion engine, it is certain that catalytic processes will not be allowed to lower that record.

"Regardless of precautions, a sizeable jolt will be given the diesel industry because of the lack of suitable quantities of high speed diesel engine fuels. If the ultimate changeover to catalytic cracking is completed, then cetane addition agents definitely will come into the picture or the diesel engine manufacturers will have to contend with a 40- to 45-cetane diesel fuel oil. Because of the important part played in the war by the diesel industry and because of its greatly expanded manufacturing facilities, it is one industry which will have much at stake through this loss of high-cetane light grades of domestic heating oils for high-speed diesel engines. The use of heating oils in the past has simplified the oil marketer's problem both of handling and availability throughout the country, but in the future this is not so.

"High cetane diesel fuels have a definite performance value for high-speed diesel engines. These give easier cold starts and shorter time from cold start to smooth running; smoother engine operation through smooth combustion, especially at part load or high speeds and no load; less exhaust odor and smoke at low speeds; lower fuel consumption at light loads, and high speeds. Under high temperatures accelerated diesel-engine tests, high-cetane fuels give longer hours before ring sticking and low cetanes aggravate ring sticking tendencies. The minimum cetane number acceptable will depend, to a great extent, on the sensitivity of the engine under consideration. Under present design there is a little improvement in engine condition above that necessary for smooth operation. Reducing cetane number below this satisfactory minimum results in increased engine fouling."

He further predicts that:

"The so-called house-brand or regular-grade gasoline will be 80-octane, such as now used by the Army for all ground vehicles using gasoline.

"The premium grade will be 87- to 90-octane, just above where Buick was when its design engineers had to cut back on octane requirements of the car.

"Diesel fuels will be available but in many geographical areas the tractor-distillate types of fuel will have to be used with low cetanes (37-40) or cetane additive agents will be added to maintain the 50-cetane minimum, such as called for by the high-speed diesel engine manufacturers.

"There will be octanes but much higher, as the refiner is provided with the 'know-how', and, of course, cetanes but fewer. It is up to the diesel engineer to utilize lower cetanes to the utmost to offset the vast lead the gasoline-engine designer, especially the aircraft engineers, has through 100-

plus-octane fuels which will be available in quantities greater than the diesel fuels after World War II."

Moore and Anderson of Union Oil Company in an excellent paper to your section said:

"It appears evident that the straight-distilled diesel fuels which we have used in the past are going to have to give way to cracked diesel fuels in the future. Unfortunately cracked stocks, as we now know them, are not satisfactory diesel fuels from the standpoints of ignition quality and resistance to gum-forming tendencies. These cracked stocks must be made stable and their ignition quality must be improved before they can be used as diesel fuels. Based on present knowledge these improvements probably will be obtained by solvent treatment of the fuels and by the use of additives, which of course will tend to increase the cost of the finished fuel."

We should now perhaps consider what is going to happen to the fuel for the gasoline engine, and just what the thinking of engine designers may be in considering the postwar gasoline truck engines. Let it be understood that by postwar engines we are thinking of four or five years after the cessation of hostilities. The catalytic processes previously mentioned, which seemed to be unfavorable to the diesel fuels, unquestionably help to secure higher-octane fuels without any appreciable cost by virtue of the process itself. Furthermore, it may well be that in the four to five years period we are speaking of, that we shall reach an octane in premium grade of around 90 to 95.

Not very long ago all our commercial airplanes operated very satisfactorily on 87-octane fuel and were able to sustain a power rating much higher than we had considered in the truck field. Therefore, in projecting our thinking into the future, it may well be that the gasoline engine for high output per cubic inch and for large gross horsepower outputs, will be designed for the premium-grade fuels. It is quite conceivable that in so doing, the industry will produce engines in which the overall ton-mile cost will be surprisingly good. This, then, puts squarely before us the future fuel picture and its problems. The other factors which have to be considered are the weight per horsepower, the output per cubic inch possible, and the price per horsepower of the two types.

Without recourse to mechanical means such as supercharging, it seems possible that we may have engines in the gasoline field in which our output per cubic inch could be increased as much as 25 percent with premium fuels available after the war. Naturally, this is going to be accomplished in several ways, but compression ratio changes will be one way, and at this juncture, it should be pointed out that our thinking in the past may have been somewhat fallacious. I am referring now to the curve of the compression ratio graph such as is contained in say, engineering which shows a falling off of the rate of power increase when the compression ratio reaches a certain optimum. This is purely theoretical and not actual because such a curve failed to take into account the very slight loss in efficiency as compared to the very large gain in output. Such a curve assumes that the friction and pumping losses go up proportionally, but, fortunately, this is not true.

The next thing which bears discussion at this stage is that of what mechanical means there are available to improve the output of engines. These come under at least two headings—solid injection of fuel, and supercharging. With regard to solid injection of fuel, that story is already well known in its application to the diesel type engine, and it is very well established that the so-called direct-ignition type offers promise from the point of view of output of gasoline engines. This is cited because of the story of European engines where the development has been through the cycle of the pre-combustion-chamber type and the improvement which they have been able to effect by the direct-injection type. The control of smoke is more difficult with a direct-injection type which, therefore, calls for more frequent and better informed maintenance than with some other types of engines. With respect to fuel injection of gasoline, it may be said that it is in its infancy as far as the truck engine is concerned. The promise is still a vague one as to the extent to which it can change the picture, but it is said that the octane requirements for a fuel-injected engine are lower than with a carbureted engine. If this is conceded, it will again be obvious that a further increase in output in the gas engine can be secured. The story of cost and also maintenance will be in line with similar diesel injection systems; therefore the percentage decrease of fuel consumption will have to be of some magnitude in the neighborhood of 15 percent, or an output of the same amount to be interesting. We, therefore, have a fascinating picture from the gasoline man's point of view in that he may expect much from the fuel itself and also an added boost from the possibilities of an economically designed fuel-injection system.

VISCOSITY OF NORMAL PENTANE
(HUBBARD & BROWN)
(Ind. Eng. Chem., Vol 35, No. 12, Dec., 1943)

		VISCOSITY IN MILLIPOISES (G./Cm./Sec. x 10^{-3})												
Pressure in Lbs./Sq. In.		Saturation	100	200	300	400	450	500	550	600	700	800	900	1000
Pressure in Kg./Sq. Cm.			7.03	14.06	21.09	28.12	31.64	35.15	38.67	42.18	49.21	56.25	63.28	70.31
Temperature, °C. and °F.														
°C.	°F.													
25	77	2.296	2.313	2.330	2.355	2.375	....	2.396	....	2.417	2.438	2.458	2.480	2.500
50	122	1.879	1.893	1.912	1.930	1.949	....	1.968	....	1.987	2.006	2.025	2.044	2.062
75	167	1.563	1.572	1.590	1.608	1.625	....	1.643	....	1.661	1.679	1.696	1.714	1.731
100	212	1.300	1.303	1.322	1.341	1.360	....	1.378	....	1.397	1.415	1.434	1.452	1.470
125	257	1.071	....	1.083	1.103	1.124	....	1.145	....	1.166	1.187	1.207	1.229	1.249
150	302	0.865	....	....	0.888	0.914	....	0.938	....	0.961	0.984	1.006	1.027	1.050
167	332.6	0.746	....	....	....	0.784	....	0.816	....	0.843	0.869	0.892	0.916	0.939
175	347	0.688	....	....	....	0.714	....	0.758	....	0.792	0.821	0.845	0.869	0.893
180	356	0.647	....	....	....	0.665	0.698	0.724	0.744	0.760	0.790	0.815	0.840	0.864
185	365	0.603	....	....	....	....	0.641	0.674	0.701	0.724	0.758	0.786	0.812	0.837
190	374	0.550	....	....	....	....	0.566	0.615	0.654	0.684	0.725	0.755	0.784	0.812
195	383	0.472	....	....	....	....	....	0.531	0.594	0.634	0.688	0.725	0.756	0.786
200	392	....	....	....	....	....	....	0.230	0.494	0.572	0.642	0.685	0.720	0.757
210	410	....	....	....	....	....	....	0.221	0.264	0.371	0.530	0.600	0.653	0.698
220	428	....	....	....	....	....	....	0.212	0.237	0.270	0.399	0.508	0.576	0.631
230	446	....	....	....	....	....	....	0.207	0.212	0.234	0.304	0.403	0.484	0.549
240	464	....	....	....	....	....	....	0.194	0.197	0.205	0.238	0.300	0.372	0.435
250	482	....	....	....	....	....	....	0.179	0.180	0.181	0.187	0.209	0.245	0.292

Chemistry in Petroleum

J. L. FRANKLIN, Humble Oil & Refining Company

A paper read before a Chemurgic Conference for Southeast Texas and the Texas Gulf Coast in Houston, July 17, 1944.

MY SUBJECT is "Chemistry in Petroleum." Thirty years ago this topic would have been little more than speculation for there was then no chemical conversion of petroleum to useful products and no chemicals manufactured from petroleum. Since 1915 the oil business has become a chemical business and its most important products have become largely products of chemical synthesis.

Originally petroleum was useful chiefly as a source of kerosine. The kerosine was recovered from crude oil by the purely physical process of distillation leaving gasoline a dangerous nuisance to be disposed of somehow. With the development of the automobile a market for gasoline developed and it became advantageous for the refiner to convert as large a part of his crude oil as possible to this product. The necessity for higher gasoline yields led to the discovery that if the heavy, involatile parts of crude oil are heated under pressure at high temperature they will undergo chemical reaction to form light volatile hydrocarbons suitable for gasoline. This process is known as cracking and with its aid larger and larger yields of gasoline have been recovered from crude oil until today it is possible, although seldom done practically, to convert over 90 percent of a crude oil to gasoline. When you consider that the average crude oil as nature provides it will contain only 10-20 percent of gasoline you can see that the chemist has provided a vastly increased supply of gasoline. Actually the motor gasoline marketed in this country before the war contained about 50 percent of natural products and the rest synthetic gasoline produced mainly by cracking. The refineries of the United States produced, before the war, about 600,000,000 barrels per year of motor gasoline. Of this, one half or 45 million tons was produced by chemical synthesis. That is an astounding quantity of synthetic chemicals. Further, after the war, the proportion of synthetic to natural material in motor gasoline undoubtedly will increase because of the increase in cracking capacity installed during the war.

Cracking originally was employed to increase the yield of gasoline recoverable from crude oil. Fortunately cracking not only gives more gasoline; it also gives gasoline of better quality than that naturally present in the crude. The main criterion of gasoline quality is its tendency to cause an engine to knock. A good fuel will cause little or no knocking whereas a poor fuel will cause the engine to knock excessively. Gasoline produced by cracking has far less tendency to cause knocking than does most virgin gasoline and so is the better fuel for automotive engines.

I would like to digress a moment to discuss the problem of engine knock in relation to fuel. Knocking is not objectionable merely because it sounds unpleasant. The tendency of a fuel to knock is an indication of the efficiency with which its energy of combustion can be converted to useful work by the engine. Thus a fuel that knocks badly can be burned successfully only in an engine having a low compression ratio and hence one that is inherently inefficient. On the other hand, a fuel with little tendency to knock can be burned in an engine having a high compression ratio and hence one that is relatively efficient. To reap the benefits of the better fuel, however, the engine must be designed to use it properly.

The measure of a fuels' tendency to knock is the octane number. This is a comparison of the knocking tendency of the fuel with that of iso-octane, a highly branched paraffin hydrocarbon having by definition an octane number of 100. On this scale the higher the octane number the less is the tendency of the fuel to knock.

Engine Design

The difference in performance between a 90-octane and a 100-octane fuel is large if the engine is designed to take advantage of it. There is no advantage, however, to employing a fuel having an octane number above that for which the engine is designed to operate satisfactorily. But an engine that is designed to employ a 100-octane fuel will operate at an efficiency approximately one third greater than an engine employing a 90-octane fuel or a reduction of about 20 percent in fuel consumption can be achieved. Thus either performance of the engine is better or the amount of fuel consumed is much less. In combat planes this means that a plane designed to operate with 100-octane fuel has the advantage in rate of climb or speed over a plane that is designed to use 90-octane gasoline. In air transport it means that bigger loads or longer flights can be achieved with the higher-octane fuel. In automobiles it means that we can have either better performance or better mileage. The American people apparently prefer to get better performance from their automobile rather than to realize a saving that can be achieved as a result of using less gasoline.

More and Better Gasoline

I mentioned before that cracking produces more gasoline and gasoline of better octane number than could be recovered from crude oil by mere physical methods. Originally cracking was accomplished by heating heavy fractions of crude oil to high temperatures, usually under pressure to cause the large molecules of the charge to break down into smaller

ones suitable for use in gasoline. Recently chemists have taken a hand in cracking and, as a result, several greatly improved cracking processes have been developed. These processes are known as catalytic-cracking processes and they are similar to the older thermal process except that the hot gases are brought into contact with a solid material, called a catalyst, which causes the chemical reactions of cracking to take place in such a way that the gasoline produced has a higher octane number and is recovered in greater yields than the gasoline from thermal (non-catalytic) cracking.

I would like to say a word about catalysts at this point, since I will have to refer to them frequently hereafter. A catalyst is anything that will change the rate of a chemical reaction. It may be a gas, liquid or solid and its function may be either to increase or decrease the speed of a reaction. Usually we use them to cause a preferred reaction to take place more rapidly than an undesirable one and thus to give us control of the quality of our product as is the case with catalytic cracking. However, frequently a catalyst may be used to reduce the speed of a reaction. Lead tetraethyl acts as a catalyst by reducing the speed of combustion of gasoline in an engine and thereby reduces its tendency to knock.

Catalytic cracking then gives bigger yields of better gasoline than the non-catalytic methods. The quality of much of the catalytic gasoline is so good, in fact, that much of it is suitable for use in 100-octane aviation gasoline. Catalytic cracking also produces large volumes of very valuable light gases, especially butylenes and propylene. Although thermal cracking produces some of these gases, the catalytic method produces more of them. A few years ago such gases were a nuisance to the refiner who could do little with them except use them for fuel. To chemists this large volume of waste material constituted a challenge which they could not ignore. In fact they answered it so vigorously and so successfully that instead of waste products these light olefins are now among the most valuable of the primary products from petroleum. Instead of being torched, the gases now are being manufactured by special process installed for that purpose. One of these special processes is catalytic cracking.

Butylenes

The most useful of these gases are the butylenes. There are two of them called normal butylene and isobutylene and both have the formula C_4H_8. They differ in that in normal butylene the four carbon atoms are linked together in a straight line whereas in isobutylene three of the carbon atoms are linked directly to a fourth central atom. The butylenes are very similar in many respects but the isobutylene is considerably more active chemically than is the normal butylene. There are two other light gases called normal butane and isobutane which are similar to normal and isobutylene except that they have two more hydrogen atoms to the molecule and thus have the formula C_4H_{10} rather than C_4H_8. The butanes are much less active chemically than the butylenes but, like them, the iso is more active than the normal compound.

Now the chemists expected iso and normal butylene to combine under the proper conditions to form a compound C_8H_{16} called a copolymer. If hydrogen were then added to the copolymer it would have the formula C_8H_{18}, an octane, and it should have a structure similar to that of iso-octane. You will recall that iso-octane was set up as the standard 100-octane fuel. Thus by two simple steps it would be possible to convert waste products to iso-octane. With such an incentive the chemists were not long in achieving their goal and several processes for polymerizing butylenes to copolymer and hydrogenating the product have been developed. In all of these the butylenes are contacted with a catalyst under pressure to form the polymer which is separated from unreacted material and reacted with hydrogen over a second and entirely different catalyst. As a matter of fact, the hydrocodimer, which is the name we give to the hydrogenated polymer, has an octane number slightly below 100 but it is nevertheless a very valuable component of aviation fuel and one that is rather inexpensive to produce.

Alkylation

But chemists are difficult people to please. This process, for all its advantages, left room for improvement. In the first place the necessity for hydrogenating required a second step to the process and this a relatively expensive one. Further, since there is usually more normal than iso-butylene in refinery gases considerable unreacted normal butylene still remained to be utilized. A few minutes ago I mentioned two other gases called butanes. If a butane, C_4H_{10} and a butylene C_4H_8 can be caused to unite we have an octane, C_8H_{18}, which would not have to be hydrogenated. Further, since butanes are plentiful, it would be possible to produce an octane for every butylene instead of just one for every iso-butylene and thus about three times as much octane would be produced and at a greatly reduced cost. Just before the war chemists from several companies succeeded in reacting isobutane with butylenes in the presence of a catalyst to produce a high octane saturated naphtha composed largely of octanes. This product was called alkylate and the process was called alkylation. It is, in my opinion, one of the greatest of all commercial chemical syntheses for it converts two abundant waste products to an extremely valuable material and it accomplishes this in a single simple operation at quite low cost. Further, the alkylation process can be used to react isobutane with several light gases other than the butylenes, among them being ethylene, propylene and the pentylenes. All of the alkylates can be used for the production of aviation fuel although some are better than others. Although I am not in a position to give the exact amount of alkylate being produced, you may be sure that it is present in considerable quantities in all of the 100-octane fuel being manufactured today and that without it and hydrocodimer this country would be unable to supply our fliers with planes superior to the enemy's or to mount the tremendous air offensives that our Armed Forces are now maintaining against all of our enemies.

The alkylation process has been so successful that we no longer look upon isobutane as a waste material but rather as a necessary premium raw material for the production of valuable finished products. In fact, as is the case with the butylenes, we now have several plants in the United States operated for the purpose of producing more isobutane. One of the most interesting of these processes is one in which normal butane is converted to isobutane. This process is called isomerization and consists of contacting normal butane with a catalyst which

causes one of the carbon atoms to change position and join the carbon chain in the middle rather than at the end. Some isobutane also is produced as a by-product of catalytic cracking and it is one of the very important credits to that process.

Synthetic Rubber

Up to now, we have considered only the manufacture of fuels, and we have seen how the butylenes and other light olefins which formerly were looked upon as nuisances and waste products have been elevated to the position of preferred raw materials. But the uses for the butylenes does not stop in their conversion to aviation gasoline. Both iso- and normal butylene have found very extensive uses in the manufacture of synthetic rubber. The normal butylene, as you recall, is composed of 8 hydrogen and 4 carbon atoms with the 4 carbon atoms linked together in a single chain. By removing two hydrogens from normal butylene we produce butadiene. This compound is the major constituent of Buna S or GRS rubber. In order to produce butadiene normal butylene is passed over a catalyst at elevated temperatures and two hydrogens are removed thereby. The butadiene is then combined with a compound called styrene in the presence of a catalyst to produce GRS rubber which is the greatest component of our synthetic-rubber program. This program calls for a total GRS rubber production of 950,000 short tons per year, 690,000 short tons per year or roughly 3/4 of which is butadiene. One third of the butadiene is made from alcohol and the remaining two thirds from butylenes from petroleum. Thus on a tonnage basis the petroleum industry is supplying 48.5 percent of the GRS production of the nation as butadiene. Butadiene also forms the biggest part of a special synthetic rubber called perbunan which is especially valuable for its solvent-resistant properties.

For the production of butadiene, it is necessary to start with normal butylene. Since the normal butylene always occurs in admixture with isobutylene, it is necessary to remove the isobutylene before the normal can be used for the production of butadiene. This is accomplished by extracting the isobutylene in a chemical process which permits its conversion either to a component of aviation gasoline or its regeneration as pure isobutylene. The pure isobutylene is recovered in case it is desired to manufacture butyl rubber from it, for isobutylene is the predominant component of butyl rubber. To produce butyl rubber, isobutylene is combined with a small amount of isoprene, a compound similar to butadiene, in the presence of suitable catalyst. Since the isoprene also is produced from petroleum, you see that butyl rubber is derived completely from petroleum.

Toluene From Petroleum

One of the most important contributions of the refining industry to the war effort has been the production of toluene from petroleum. During the last war toluene was made almost entirely from coal tar. It was recognized before the start of hostilities, however, that the toluene available from this source would be far from sufficient to support the prosecution of a modern war, and consequently, the oil industry was looked to for the production of a large part of the toluene necessary for the manufacture of TNT for explosives. There is a small amount of toluene present in most crude oils and some of this is being manufactured by simple extraction processes. The vast majority of the toluene now being manufactured in the United States, however, is synthesized from other types of hydrocarbons by a process known as hydroforming. By this process, naphthenic hydrocarbons segregated from petroleum are passed over a catalyst at elevated temperatures where hydrogen is removed leaving aromatic hydrocarbons as the main product. The toluene is being produced by this process at a rate from five to six times as great as that from coal tar. Since most all of this is used in explosives, it is evident that without the toluene from petroleum it would have been impossible to produce a sufficient amount of TNT to carry on the war. It is of interest to note that aromatic hydrocarbons other than toluene are produced simultaneously with the toluene in the hydroforming process. Thus xylenes and ethylbenzene are produced in quite large quantities and these materials being of high octane number, are useful in the manufacture of aviation gasoline. After the war, however, it is anticipated that a large volume of aromatics from this source will be converted to plastics, lacquer, solvents, and special chemicals.

Chemicals

Perhaps the most fruitful source of organic chemicals for sale to the consumer is the light olefins, namely, ethylene and propylene. From these compounds, which originally were considered to be waste products of refining, the oil industry is now producing a large volume of chemicals. From ethylene, ethyl alcohol is manufactured by a simple catalytic process in which the ethylene, C_2H_4, is combined with water to form ethyl alcohol, C_2H_{60}. About sixty million gallons per year of ethyl alcohol are now being produced from ethylene by the oil and chemical industries, and no doubt after the war a great deal more of this valuable chemical will be thus synthesized from petroleum. Ethylene is likewise converted in large quantities to ethyl chloride which is used primarily for the production of tetraethyl lead which is, as you all know, used in gasoline to suppress its knocking properties. In addition, ethylene is used for the manufacture of ethylene glycol and, indirectly, of acetic acid by the oxidation of ethyl alcohol.

I said that ethylene originally was considered to be a waste product of the cracking of petroleum. The amount of ethylene available in sufficient concentration in the waste gases from refining is, however, not sufficient to support large chemical manufacturing processes, and, consequently, as in the case of the butylenes, we have had to install processes for the manufacture of ethylene to be used for the subsequent synthesis of chemicals such as ethyl chloride and alcohol. Ethylene is produced by cracking propane, a light hydrocarbon present in large quantities in the residue gas from natural-gasoline plants.

From propylene, which is C_3H_6, isopropyl alcohol, acetone, glycerine and many other compounds are manufactured. The isopropyl alcohol is not suitable for beverage purposes but is finding a wide range of uses in cosmetics, cleaning compounds, and solvents. Propylene is available in large quantities from catalytic cracking operations.

I have discussed the major lines of bulk chemicals produced from petroleum. There are a number of special by-product chemicals produced in volumes varying from a few gallons per day to several tons

per day in various refineries. Among these are soaps and detergents, especially hard-water soaps such as are used in shampoos; naphthenic acids, that find special uses in paints and varnishes; phenols, mercaptans, nitrogen bases, asphalts, waxes, and some resins and drying oils.

Natural Gas

So far, I have discussed almost exclusively the synthesis of chemicals from petroleum. Closely kin to petroleum, of course, is natural gas, which is composed largely of methane, the smallest member of the paraffin series and the most difficult to react chemically. Methane is a very light gas having the formula CH_4 and because of its chemical inactivity, its main utility thus far has been as fuel. However, it is the main source of carbon black and this is used as a rubber extender and pigment. The carbon-black business is a large one and results in the production of about 250,000 tons per year of carbon black. Natural gas also is a source of the greater part of hydrogen that is used in this country for the production of ammonia. The hydrogen is produced by cracking methane catalytically to separate the hydrogen from the carbon. This hydrogen is then reacted with nitrogen to form ammonia. Natural gas is likewise the source of a number of other chemicals including the nitroparaffins which are used as solvents and a starting point for various chemical synthesis and formaldehyde which you may know as a fumigant.

Petroleum Additives

In addition to chemicals for sale as such, the oil industry produces quite a large number of special chemicals that it consumes itself, as additives for improving the performance of its fuels and lubricants. For example, tetraethyl lead, although not manufactured by the oil industry is manufactured in part from petroleum materials and is used entirely to improve the quality of gasoline. Similarly, a large number of such quality improvers are manufactured for use in lubricating oils. Although the chemical natures of these compounds are trade secrets and cannot be divulged, they serve a number of useful purposes and with their aid you are now supplied with lubricants of quality beyond anything dreamed of ten years ago. Among these additives are detergents to prevent deposition of varnish and sludge in the engine, anti-oxidants and corrosion preventives to assure long life to bearings and alloy metals, pour-point depressants to prevent wax crystallization at low temperatures and aid in starting under winter conditions, viscosity-index improvers which give improved lubrication over a wider range of temperature conditions than could otherwise be achieved, dyes to improve color and appearance, and film strength improvers. In fact, lube-oil manufacturers are beginning to look upon petroleum as merely a vehicle for carrying these additives which themselves furnish the desired protection to your engine.

I have mentioned a number of chemicals that are produced from petroleum and from the figures I have given, no doubt, it seems that they represent a large fraction of the petroleum that is refined. As a matter of fact, although the total amount of chemicals produced from petroleum is large, it represents only a very small percentage of the total petroleum used by this country. For example, all of the butadiene that is produced for the synthetic rubber program is equivalent to only some 12,000 barrels per day of butadiene, whereas, over four million barrels per day of petroleum is being refined currently. The sixty million gallons per year of ethyl alcohol produced from petroleum is about one third of the total ethyl alcohol manufactured under normal conditions and sounds like a tremendous quantity of material. Compared to crude-oil production of 1½ billion barrels per year or 60 billion gallons per year, however, this is really a very small quantity. Even our 100-octane production which is in the order of 400,000 barrels per day or about 150 million barrels per year represents only about 10 percent of the total crude oil produced in this country, although, in terms of chemicals, it is a tremendous amount of material. Petroleum is an expanding source of chemicals, and no doubt in the future will be the source of vastly greater quantities of these materials, but chemicals produced from petroleum probably will not constitute a significant drain upon our petroleum sources for many years, if ever.

Petroleum in War

At present, the oil industry is devoted completely to the manufacture of materials for war. Much of this manufacture of war materials is carried out in plants owned or financed by the government. This is especially true of those plants for the manufacture of toluene, butadiene, and rubber. On the other hand, by far the largest investment in 100-octane plants was made by the oil industry itself. No doubt, when the war is over, there will be a reduction in the amount of 100-octane required for aviation services, and in the demand for toluene for use in explosives. Perhaps, some of the plants manufacturing rubber and rubber raw materials will likewise not be needed for these purposes. It is, of course, impossible to predict the extent of these shutdowns that will occur. The government may wish to retain some shutdown plants intact for use in case of another war. It is probable, however, that some of those plants will be converted to other processes and other uses will be found for many of the products that are now going into war materials. Thus, it is probable that butadiene and aromatics, after the war, will find their way in large quantities into plastics and resins. You can be confident also that new processes will be developed for converting waste materials to chemicals and for manufacturing specific hydrocarbons of a special value for use in aviation gasoline. It is probable also that the oil industry will produce larger quantities of chemicals such as alcohols after the war. Although, we do not anticipate a serious crude oil shortage in this country for some time, the shortages of wartime have brought home to us the fact that our petroleum is a priceless resource and that we should make the most that we can of it. Consequently, you can be confident that the oil industry will convert larger and larger percentages of crude oil to chemicals and other products more valuable than fuel and that it will strive harder and harder to produce better fuels so that you can have better planes and automobiles and cheaper transportation.

Boiler Feed Water Chemistry

Boiler Feed Water Impurities

Name	Formula	Produces
Calcium sulfate (Gypsum)	$CaSO_4$	Hard scale.
Calcium carbonate	$CaCO_3$	Soft scale.
Calcium bicarbonate	$Ca(HCO_3)_2$	Soft scale. Liberated CO_2 can corrode.
Calcium nitrate	$Ca(NO_3)_2$	Corrosion by acid formation.
Calcium chloride	$CaCl_2$	Magnesium chloride by reacting with any magnesium sulfate.
Magnesium sulfate	$MgSO_4$	Corrosion when in presence of chlorides.
Magnesium chloride	$MgCl_2$	Acid corrosion.
Magnesium carbonate	$MgCO_3$	Corrosion when in presence of chlorides.
Magnesium bicarbonate	$Mg(HCO_3)_2$	Soft scale. Liberated CO_2 can corrode.
Silica (soluble)	SiO_2	Hard scale.
Carbonic acid or CO_2	H_2CO_2 or CO_2	Tendency towards corrosion by preventing formation of carbonate scale.
Oxygen	O_2	Corrosion by depolarizing metal surfaces.

Chemicals for Removing Boiler Water Impurities

Chemical	Formula	Impurities Removed
Sodium carbonate (Soda ash)	Na_2CO_3	Calcium sulfate, calcium chloride, calcium nitrate, magnesium sulfate, magnesium chloride. Or and acid.
Sodium hydroxide (Caustic soda)	$NaOH$	Magnesium sulfate, magnesium chloride, calcium bicarbonate, magnesium bicarbonate Or and acid.
Trisodium phosphate	Na_3PO_4	Calcium sulfate, magnesium sulfate, magnesium chloride.
Sodium silicate (Water glass)	Na_2SiO_3 (Ratio varies)	Calcium sulfate, magnesium sulfate, magnesium chloride, most acids.
Calcium hydroxide (Milk of lime)	$Ca(OH)_2$	Carbonic, sulfuric, or other acids, calcium bicarbonate, magnesium bicarbonate.
Barium hydroxide (Barium hydrate)	$Ba(OH)_2$	Magnesium sulfate, sulfuric acid, carbonic acid.
Barium carbonate	$BaCO_3$	Calcium sulfate, magnesium sulfate, sulfuric acid.
Sodium zeolite	Na_2Z (Descriptive Z for zeolite refers to complex alumino-silicate with base-exchange properties.)	Substitutes sodium for calcium and magnesium in: Calcium and magnesium sulfates, calcium and magnesium chlorides, calcium and magnesium bi-carbonates, and calcium and magnesium nitrates. The sodium compounds brought about through exchange are soluble and do not form scale.

Chemical Reactions in Treatment of Boiler Water

$$CaSO_4 + Na_2CO_3 = \mathbf{CaCO_3} + Na_2SO_4$$
$$CaCl_2 + Na_2CO_3 = \mathbf{CaCO_3} + 2NaCl$$
$$Ca(NO_3)_2 + Na_2CO_3 = \mathbf{CaCO_3} + 2NaNO_3$$
$$MgSO_4 + Na_2CO_3 = \mathbf{MgCO_3} + Na_2SO_4$$
$$MgCl_2 + Na_2CO_3 = \mathbf{MgCO_3} + 2NaCl$$
$$H_2SO_4 + Na_2CO_3 = H_2CO_3 + Na_2SO_4$$

$$Na_2CO_3 + H_2O + \text{Boiler heat} = 2NaOH + CO_2 + H_2O$$
$$Ca(HCO_3)_2 + \text{Boiler heat} = \mathbf{CaCO_3} + CO_2 + H_2O$$
$$Mg(HCO_3)_2 + \text{Boiler heat} = \mathbf{MgCO_3} + CO_2 + H_2O$$

$$MgSO_4 + 2NaOH = \mathbf{Mg(OH)_2} + Na_2SO_4$$
$$MgCl_2 + 2NaOH = \mathbf{Mg(OH)_2} + 2NaCl$$
$$H_2SO_4 + 2NaOH = Na_2SO_4 + 2H_2O$$
$$H_2CO_3 + 2NaOH = Na_2CO_3 + 2H_2O$$
$$Ca(HCO_3)_2 + 2NaOH = \mathbf{CaCO_3} + Na_2CO_3 + 2H_2O$$
$$Mg(HCO_3)_2 + 4NaOH = \mathbf{Mg(OH)_2} + 2Na_2CO_3 + 2H_2O$$

$$3CaSO_4 + 2Na_3PO_4 = \mathbf{Ca_3(PO_4)_2} + 3Na_2SO_4$$
$$3MgSO_4 + 2Na_3PO_4 = \mathbf{Mg_3(PO_4)_2} + 3Na_2SO_4$$
$$3MgCl_2 + 2Na_3PO_4 = \mathbf{Mg_3(PO_4)_2} + 6NaCl$$

$$CaSO_4 + Na_2SiO_3 = \mathbf{CaSiO_3} + Na_2SO_4$$
$$MgSO_4 + Na_2SiO_3 = \mathbf{MgSiO_3} + Na_2SO_4$$
$$MgCl_2 + Na_2SiO_3 = \mathbf{MgSiO_3} + 2NaCl$$

$$H_2CO_3 + Ca(OH)_2 = \mathbf{CaCO_3} + 2H_2O$$
$$Ca(HCO_3)_2 + Ca(OH)_2 = \mathbf{2CaCO_3} + 2H_2O$$
$$Mg(HCO_3)_2 + 2Ca(OH)_2 = \mathbf{Mg(OH)_2} + \mathbf{2CaCO_3} + 2H_2O$$

$$CaSO_4 + Ba(OH)_2 = \mathbf{BaSO_4} + Ca(OH)_2$$
$$MgSO_4 + Ba(OH)_2 = \mathbf{Mg(OH)_2} + \mathbf{BaSO_4}$$
$$H_2CO_3 + Ba(OH)_2 = \mathbf{BaCO_3} + 2H_2O$$

$$CaSO_4 + BaCO_3 = \mathbf{BaSO_4} + \mathbf{CaCO_3}$$
$$MgSO_4 + BaCO_3 = \mathbf{BaSO_4} + \mathbf{MgCO_3}$$

$$MgSO_4 + 2NaCl = MgCl_2 + Na_2SO_4$$
$$MgCl_2 + 2H_2O = Mg(OH)_2 + 2HCl$$
$$FeCl_2 + 2H_2O = Fe(OH)_2 + 2HCl$$
$$FeSO_4 + 2H_2O = Fe(OH)_2 + H_2SO_4$$

$$CaSO_4 + Na_2Z = CaZ^* + Na_2SO_4$$
$$MgSO_4 + Na_2Z = MgZ^* + Na_2SO_4$$
$$CaCl_2 + Na_2Z = CaZ^* + 2NaCl$$
$$MgCl_2 + Na_2Z = MgZ^* + 2NaCl$$
$$Ca(HCO_3)_2 + Na_2Z = CaZ^* + 2NaHCO_3$$
$$Mg(HCO_3)_2 + Na_2Z = MgZ^* + 2NaHCO_3$$

* Upon regeneration with a strong salt (NaCl) brine, the zeolite is converted back to Na_2Z. The calcuim and magnesium chlorides formed during the "exchange" regeneration (CaZ or $MgZ + 2NaCl = Na_2Z + CaCl_2$ or $MgCl_2$) are disposed of as waste.

The formulas in **heavy type** indicate precipitates, or sludges.

Lime and Soda Ash Requirements Per Thousand Gallons Water and Amount of Sludge Formed

Pounds Milk of Lime ($Ca(OH)_2$) Per Thousand Gallons Water

Grains per Gallon, Hardness	Calcium Bicarbonate	Magnesium Bicarbonate	Calcium Carbonate	Magnesium Chloride	Magnesium Sulfate	Magnesium Nitrate
5	.36	.80	.59	.62	.49	.40
10	.72	1.61	1.17	1.23	.98	.79
15	1.09	2.41	1.76	1.85	1.46	1.19
20	1.45	3.21	2.35	2.46	1.95	1.58
25	1.81	4.02	2.94	3.08	2.44	1.98
30	2.17	4.82	3.52	3.70	2.93	2.38

Pounds Soda Ash (Na_2CO_3) Per Thousand Gallons Water

Grains per Gallon, Hardness	Calcium Sulfate	Calcium Chloride	Magnesium Sulfate	Magnesium Chloride	Calcium Nitrate	Magnesium Nitrate	Sulfuric Acid
5	.56	.68	.63	.80	.46	.51	.77
10	1.11	1.36	1.26	1.59	.92	1.02	1.54
15	1.67	2.05	1.89	2.39	1.39	1.53	2.32
20	2.22	2.73	2.52	3.18	1.85	2.04	3.09
25	2.78	3.41	3.15	3.98	2.31	2.55	3.86
30	3.34	4.09	3.78	4.77	2.77	3.06	4.63

Pounds Sludge Formed Per Thousand Gallons Water Softened By Lime and Soda

Grains per Gallon, Hardness	Calcium Bicarbonate	Magnesium Bicarbonate	Calcium Chloride	Magnesium Chloride	Calcium Sulfate	Magnesium Sulfate
5	.89	1.31	.64	1.19	.53	.94
10	1.78	2.62	1.28	2.38	1.06	1.88
15	2.67	3.93	1.92	3.57	1.59	2.82
20	3.56	5.24	2.56	4.76	2.12	3.76
25	4.45	6.55	3.20	5.95	2.65	4.70
30	5.34	7.86	3.84	7.14	3.18	5.64

Recent Advances in Manufacture Of Synthetic Lubricants From Kogasin

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Translated by E. J. Barth

IN our early work on synthesizing lubricants from raw products derived from the water-gas reaction of Fischer-Tropsch, we selected the high-boiling raw synthetic product called "gasoil."[2]

In order to make it reactive in subsequent reactions this material was converted into various chloro-derivatives, which were then easily reacted with aromatics, using aluminum chloride, in typical Friedel-Craft's reactions. By such procedure synthetic lubricants with any desired viscosity could be obtained; the oils, fluid at quite low temperatures, very resistant to oxidation, showed low coke values. They had, however, the undesired property of being quite susceptible to temperature changes. In other words, their viscosity index is quite low (about 0 or slightly lower). We had investigated earlier to improve this low viscosity index by a follow-up procedure of hydrogenation. As a matter of fact, we were able to considerably improve the synthetic oils along several lines. It was remarkable to observe the water-white color of the hydrogenated product, and the absence of any sign of oxidation tendencies, for instance, indicated what hydrogenation would do. Contrary to expectation the viscosity index could not be materially raised. These observations finally convinced us that our oils, made by condensing the paraffinic kogasin molecules with aromatics or hydroaromatics, compared favorably in many respects with the usual or natural petroleum lubricants — especially as to their high viscosity, and many other properties, and that their peculiarly low viscosity index was entirely a matter of chemical constitution.

We therefore opened up a program to look into the problem of improving the viscosity index of our oils in order to obtain super-lubricants, if such were possible. We decided as a basis of work that, even though the aromatic ring could still be the basis of building up a true lubricant molecule, the paraffinic side chains would have to be increased considerably or lengthened if necessary. It is well known to investigators in this field that even though the paraffin hydrocarbons, (normal hydrocarbons) are notoriously thin liquids, without appreciable viscosity, they show the least temperature susceptibility of any of the series of hydrocarbons.

One possibility in aiming to secure greater "paraffinity" in the synthetic product is to hold the aromatic to be used fairly low relative to the percent of the chloro-kogasin; under such conditions it is favorable to alkylate completely the aromatic nucleus.

Another possibility is also based on the following: in previous work we usually obtained low-boiling synthetic hydrocarbons besides the high-boiling viscous material. These low fractions represent partially alkylated aromatics with a deficiency of alkyl chains in the molecule. We have therefore used these low fractions in further reacting with chloro-kogasin to form more highly alkylated material.

By both procedures synthetic lubricants are obtained containing highly alkylated aromatics which fulfilled our hopes for material with flat viscosity curves. Table 1 shows the results of several experiments indicating how the viscosity index varies with the increase in paraffinic material used in the syntheses.

TABLE 1

Relationship of Viscosity-Index and Condensation Reactants

Exp. No.	Lubricant From	Specific Gravity $D^{20}/_4$ C.	Viscosity, °E. At 20 °C.	Viscosity, °E. At 50° C.	Pole Height	V. Index
1	Trichlorokogasin + Xylol	0.925	35.0	5.2	3.98	23
2	Dichlorokogasin + Xylol mol. Ratio 1:5	0.904	15.8	3.3	3.02	28
3	Dichlorokogasin + Xylol mol. Ratio 1:0.5	0.903	20.6	4.42	2.01	90
4	Dichlorokogasin + Light Aromatics	0.900	45.8	8.35	1.93	100

The first experiment is one using xylol and a trichloro-kogasin yielding an oil of high specific gravity —0.925 and the unsatisfactory viscosity-index of 23. Using in the condensation a dichloro-kogasin with xylol, we obtained the next two oils where the amount of chloro-derivative used becomes manifest in securing better viscosity index. In the case of oil No. 3 only one tenth of the xylol was used as in oil No. 2, resulting in a still lower viscosity index on the finished oil. Oil No. 4 is a typical condensation product making use of the low-boiling-point fractions from a previous condensation. In this case the viscosity index has been materially increased.

After we succeeded in producing the above oils by holding the aromatic content at a minimum we investigated whether or not we could even dispense entirely with the aromatics and react the raw products derived from the water-gas synthesis.

In this series of experiments we chose to make the kogasin molecule reactive by the usual procedure of introducing chlorine; in other words, it was a case of splitting off chlorine in the form of hydrogen chloride to obtain olefines, and subjecting the latter to polymerization—or, a condensation reaction among the olefines. There are several literature references and procedures have been proposed to pro-

duce synthetic lubricants by first chlorinating fractions of petroleum—preferably the solid paraffins, and then dechlorinating to obtain the condensed products. H. Van Werth[2] has recently reviewed the patent literature dealing with the preparation of synthetic lubricants from paraffin.

Still more recently Tanaka and co-workers[3] chlorinated hard wax, thermally dechlorinated the chloro-product at 300°C. in which process viscous oils were formed. The characteristics of the oils so formed were not given, and it would appear that the products so formed under high-temperature conditions can hardly be classed as high-grade lubricants, since it is well known that lubricants are thermally unstable in such temperature ranges.

Evidently it is more feasible to catalytically dechlorinate and to carry out, if possible, a polymerization of the unsaturated olefines that are so formed. For this purpose activated aluminum (by amalgamation) appeared to us especially adapted since it is active material for producing aluminum chloride in nascent form, and had been previously used successfully in cracking oils in the presence of gaseous hydrogen chloride instead of using ordinary aluminum chloride.[4]

We have, therefore, carried out condensations of chloro-kogasin alone solely with activated aluminum metal and have found that we can obtain substantially good yields of lubricants in this manner.

The procedure is as follows: it appears that the traces of H Cl gas which are usually always present in chlorinated oils are effective in immediately reacting with the activated metal to form small amounts of aluminum chloride, which is very reactive being formed nascently in this manner, and which is the catalyst which at once proceeds to dechlorinate the remainder of the chloro-product, liberating H Cl gas at low temperatures. After some small induction period has elapsed the reaction proceeds to speed up until eventually all chlorine has been removed and split off in the form of H Cl; in the meantime, the intermediate formed unsaturateds have undergone a polymerization to viscous oils. An advantage of this procedure using activated metal is that reactions proceed to completion using only one fourth of the quantity of aluminum chloride as would ordinarily have to be used. This amounts to a 50 percent cost reduction, in general.

Activated aluminum metal is easily prepared by the method of Neesen[5]. Commercial sheet aluminum about 0.5 mm. thickness was cut in squares of 1 cm, etched with sodium hydroxide solutions, and at once treated with a 1 percent solution of mercuric chloride. The pieces are dried, and will be found to be very active. In moist air the pieces will heat up due to the formation of aluminum hydroxide.

For our synthetic work in the lubricant field we reacted the various chloro-kogasins with 2.5 percent activated aluminum metal, heating the oil in a stirring-flask. After 1—2 hours copious evolution of H Cl gas took place, which had ended in about 2—15 hours at 130°C., depending on the original chlorine contents. When the reaction was complete the oily mass was allowed to settle, and the top thinner oil was decanted from the very viscous aluminum chloride sludge below. The separated oil is conveniently freed of suspended Al Cl_3 sludge particles by contacting with 1 percent weight of some good activated clay and filtering in the hot through a suction filter. This procedure is much simpler than water-washing and it produces clear sludge-free oil, free of occluded H Cl gas. Eventually the oil is distilled in a vacuum to 200°C., yielding a lubricant of viscosity equal to commercial motor oil. The Al Cl_3 addition compound (sludge) can be re-used several times again as a catalyst in succeeding reactions. We have found the addition-compound to be even more reactive than the activated metal so that the reaction takes place at room temperature and must often be cooled in order to slow it up. In other words, it becomes possible to convert large quantities of chloro material with only small quantities of activated metal. The results of the reactions made in this manner are shown in Table 2.

One notes from these results that much more viscous oils result from dichloro-kogasin than when using monochloro-kogasin. The specific gravity is appreciably lower than from oils made by alkylating the aromatics and is more nearly similar to the gravities of natural lubricants. The decrease in viscosity with temperature increases is very small—the values of 38-125 V.I. are similar to the natural lubricants. An exception is seen in case 5 products where a temperature of 200°C instead of 130°C was employed. The unfavorable influence of the higher temperature for the prolonged reaction time becomes evident in the higher specific gravity and in a steeper viscosity curve (low V.I. of 38). The yields shown are based on the raw product which, when calculated on the volume of chloro-kogasin that is used, are of the order of 80 percent or higher. The decrease of 20 percent in volume is due to the higher specific gravity of the lubricant as to the dichloro-kogasin (0.87 against 0.77); also a portion of the synthetic oil is held up by the Al Cl_3 sludge.

After a method was thus found to obtain lubricants from kogasin by way of the chloro derivatives, thus circumventing the use of aromatics to make high-grade lubricants, we next directed our efforts to make these oils direct from the products of the benzine synthesis, without the use of chlorination of the products. It is known, of course, that the paraffinic material present in our syntheses product is non-reactive as to polymerizations, condensations, etc., so that we could only consider the olefinic fractions of our raw product as material which is truly reactive. The literature is quite complete concerning the polymerization of olefines to lubricants, previously mentioned.[1] Of especial interest are the results obtained by Sullivan and co-workers[6] in their systematic work

TABLE 2

Preparation of Lubricants from Chlorinated Kogasin

Exp. No.	RAW STOCK	LUBRICANT TESTS							
		Yield Volume-Percent	Specific Gravity $^{20}/_{4}$ C.	n $^{20}/_{D}$	Specific Ref.	Viscosity, °E. 20° C.	Viscosity, °E. 50° C.	Pole Height	Viscosity Index
1	Monochlorokogasin + 2.5 percent Al	33	0.857	1.4782	0.558	21.3	5.0	1.58	125
2	Monochlorokogasin + $AlCl_3$-sludge	29	0.842	1.4704	0.559	10.4	2.9	1.72	94
3	Dichlorokogasin + 2.5 percent Al	41.5	0.874	1.4863	0.557	39.4	7.6	1.77	87
4	Dichlorokogasin + $AlCl_3$-sludge	29	0.837	....	....	9.3	2.8	1.68	118
5	Dichlorokogasin + $AlCl_3$-sludge (70 hrs. 200° C.)	39	0.907	1.5217	0.576	29.2	5.3	2.4	38

on the higher olefines which were obtained by careful cracking of paraffins and paraffin wax.

The unsaturateds in the products from our water-gas reaction can be reacted or polymerized in a variety of ways; the catalyst used in the synthesis reaction determines to a great extent the degree of saturation of the synthetic benzine and again the composition of the raw gases exerts a powerful influence also on the olefin contents of the products.

TABLE 3

Relation Between Olefin Contents, Type of Catalyst and Raw Gas Composition

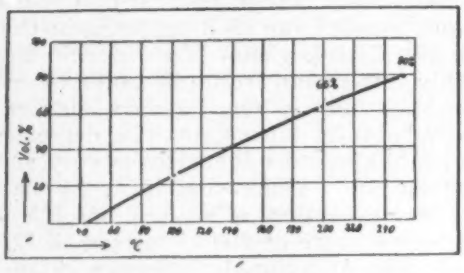
Metallic Catalyst	Vol.—Percent Olefin in Syn. Benzine when Using: Water-Gas 1 CO: 1H₂	Mixed Gas 1 CO: 2H₂	Cracked-Gases 1 CO:3H₂
Cobalt	55	35	12
Nickel	35	16	5

TABLE 4

Boiling Range of Kogasin and Distribution of Its Olefines

Boiling Point Curve

Olefines



	Volume-Percent	Olefin Content
Total Product	100	26.
Fraction 50–100° C	22.5	39.
Fraction 100–150° C	20.0	27.
Fraction 150–200° C	19.5	18.
Fraction 200–250° C	13.0	11.

As can be seen from Table 3, all the cobalt catalysts yield a considerably richer material in olefines than do the nickel catalysts. The relationship of carbon monoxide to hydrogen, which is 1:1 in the case of water-gas, 1:2 in mixed gas, and 1:3 in cracked or producer gas, affects the saturation of the final syntheses Fischer-Tropsch products. Water-gas, in other words, contacted with a cobalt catalyst will furnish a syntho-benzine of over 50 percent reactive olefines.

Pursuing our work in this direction we worked exclusively for a while with the olefin hydrocarbons present in kogasin. We employed 75 liters of kogasin in order to have enough final product for all tests—this material having been produced from a mixed gas containing 28 percent C O and 56 percent hydrogen by way of a cobalt catalyst. Table 4 shows the boiling-point curve and olefin contents of individual cuts made in a test distillation. Approximately 65 percent boils up to 200°C, 80 percent to 250°C. The whole product contains 26 percent olefines but these are not evenly distributed over the whole boiling range. The lower cuts are richer in olefin contents than the high-boiling material. The residue over 250°C contains practically no olefin material, and cannot therefore be polymerized. The polymerization is simply carried out. The olefinic fraction is reacted by violent stirring with 5-10 percent anhydrous aluminum chloride by weight at about 50-100°C. When the reaction is completed (10-20 hours), the crude product is decanted from the aluminous sludge, and the top oil freed of sludge particles by use of clay, as previously described. The product is next distilled to remove any low- or middle-boiling fractions of no viscosity or other through saturated material from the high-boiling residual oil, which will show viscosity. The reaction product will be almost quantitative in yield except for a small amount of oil held up in the heavy aluminum chloride sludge.

In Table 5 are shown the results of several of the polymerization reactions.

In the second column the boiling point of the original olefin fractions are shown, arranged in increasing order. The conditions of the reactions are shown in column 3. The time of reaction is indicated as from 8 to 32 hours, at temperatures of from 57°-99° C, except in experiment No. 1, carried out at 30°-50° C due to the low boiling point of this fraction. The yield of lubricants is shown in weight percent of the olefin fraction employed. In following columns are shown such constants as specific gravity, refractive index, viscosity, etc. The yield is approximately 45-50 percent by weight. The lower yields in tests 1, 7 and 8 are one to incomplete polymerization of those olefines in the fractions, as indicated for the boiling point of these cuts. Increasing the time from 8 to 32 hours, or a rise of temperature from 57 to 99°C has practically litle effect on the yield or nature of the polymerized oil, as shown by experiments 4, 5 and 6. Specific gravity is very low in all cases—between 0.83 and 0.84. Refractive index and specific refraction indicates a great similarity among the several oils regardless of the raw original fraction used. Viscosity is of course higher where a higher-boiling cut was used, and can be increased in any case by further distilling small amounts of low-boiling-point distillates from the synthetic oil—as will be shown later. A noticeable improvement in viscosity index is apparent; the viscosity index increases with increase in boiling point of the raw fraction. It indicates that the higher fractions of olefinic kogasin are more suitable for high-viscosity index oils than are the low-boiling cuts. Using the characteristic index

TABLE 5

Polymerization of Olefine Containing Kogasin Fractions into Lubricants

Experiment No.	Raw Fraction	Time and Temp. °C.	Vol.-Percent Olefines in B.P. Range of Raw Cut: Before The Polymerization	After The Polymerization	Yield in Weight-Percent of Olefines	SYNTHETIC OIL: Specific Gravity D 20/4	n 20/D	Specific Refr.	Viscosity, °E. 20° C.	Viscosity, °E. 50° C.	Pole Height	Viscosity Index
1	50–100° C.	8.5 H; 50°	39.	14.5	25.5	0.835	1.4656	0.557	29.9	4.75	3.59	5
2	100–150° C.	8.0 H; 57°	27.	2.0	46.5	0.836	.....	....	28.1	4.80	3.01	10
3	100–150° C.	32 H; 57°	27.	1.0	44.5	0.839	1.4664	0.556	38.0	6.01	2.95	33
4	150–200° C.	8 H; 57°	18.	2.0	47.5	0.835	1.4668	0.558	18.7	4.0	2.28	43
5	150–200° C.	32 H; 57°	18.	1.0	51.0	0.839	1.4667	0.557	20.7	4.27	2.24	63
6	150–200° C.	8 H; 99°	18.	1.0	48.0	0.840	1.4672	0.556	19.7	4.0	2.4	59
7	200–250° C.	8 H; 57°	11.	8.0	19.5	0.827	1.4617	0.558	6.12	2.17	1.69	120
8	200–250° C.	8 H; 99°	11.	6.0	22.0	0.832	.....	....	6.09	2.16	1.73	110

called "pole height" (Walther), this figure is low for high viscosity index oils, such as 1.7 pole height, and is a high value for the low-viscosity-index oils. For instance, a pole height of 3.6 is characteristic for naphthene-base oils, while the Pennsylvania oils show by this scale a value of 1.7.

These observations are in agreement with the results of Sullivan and co-workers,[6] given in Table 6, next to our own results.

TABLE 6

Relationship Between Pole-Height or Viscosity Index and the Boiling-Point of the Olefinic Raw Fraction

Tests by Sullivan & Co-workers			Our Values		
Polymerized Olefin	Visc. Pole Height	V.I.	Polymerized Cuts or Kogasin	Visc. Pole Height	V.I.
Pentene—2	3.41	27	50–100° C.	3.59	5
			100–150° C.	2.95	33
Hexene—1	2.04	91	150–200° C.	2.28	43
Octene—1	1.74	104	200–250° C.	1.69	117
Cracked Distillate about 150–250° C.	2.00	95	150–250° C.	2.02	93

The American investigators employed fairly pure olefines in their work. These cuts were then diluted with inert naphtha and reacted with aluminum chloride. Their reaction conditions were almost identical to ours. We calculated the viscosity index from the values given by the above workers. As can be seen, the lubricant from pentene shows about the same viscosity index as our oil from the 50°-100°C. kogasin cut—with increase in molecular weight there is the decrease in viscosity index. A cracked distillate prepared from a paraffinic crude oil cut yields a lubricant of pole height 2, equal to that made from a fraction of 150°-250°C. kogasin. (95 viscosity index).

As mentioned above, the actual viscosity of these synthetic oils can be arbitrarily increased by distilling off some light ends. This procedure was investigated in the case of an oil made from a 150°-200°C. fraction. The results are shown in Table 7.

TABLE 7

Vacuum Distillation of a Synthetic Lubricant

	Viscosity °E.		Visc. Pole Height	Visc. Index
	20° C.	50° C.		
Original Lubricant I	18.7	4.0	2.28	43
20 percent Distilled off, Lube II (Vol.)	34.8	6.0	2.47	35
Another 20 percent Distilled off (Vol.) Lube III	58.6	9.04	2.31	40
Distillate I–II—20 percent off Vol. of Oil I	3.06	1.56	2.30	41

The original lubricant showed a viscosity of 18.7 E. at 20°C. Twenty percent of distillate was then removed by distillation at 0.5 mm. so that now the oil showed 34.8E. Later, another 20 percent by volume of distillate was removed in another distillation obtaining now a viscosity of 58.6E. Even though the actual viscosity of the three oils is quite different, their pole height or viscosity index lies in about the same range. Even the low viscosity oil (distillate) of only 3.06E. shows the same viscosity index as the others. From these facts it is evident that these synthetic oils are characterized by similar polymer structure, pointing to hydrocarbons of identical types and very little branching.

As a temporary summary it can be said at this point therefore that the simple kogasin olefines polymerized to lubricants do yield a good improvement over the oils one obtains with the aromatics and the chloro-kogasins. The first noticeable improvement that is obtained is the significant low temperature-viscosity susceptibility, the low paraffinic specific gravity, and the high content of hydrogen. The oils made by condensing the chloro-kogasins and those by olefin polymerization are identical in values for the above-mentioned tests; one can therefore note that they consist of hydrocarbons of similar structure. In Table 8 are given several of the three various procedures for obtaining these lubricants—the main physical and chemical properties of which are there summarized.

Procedure No. 1 indicates the condensation of chlorinated kogasin with the aromatic hydrocarbons; according to procedure No. 2 the oil from the chlorinated kogasin is shown as being made from that one constituent. In procedure No. 3 are shown the results of straight polymerization of olefinic fractions. It can be clearly seen that the lubricants made in the condensation with the aromatics still show a rather high gravity even after they are hydrogenated —higher than those produced directly from kogasin itself. The refractive index is also higher in the first case than in the case of the other two types, while the specific refraction shows no appreciable differences between these oils.

As to the ultimate analysis of these oils, the condensation product before being hydrogenated takes an intermediate position due to its low hydrogen content; the latter is increased to 13 percent by hydrogenation which brings it within the category of the natural lubricating oils. This value is also shown by the other remaining oils.

The viscosity index, it should be noted, is definitely in the favorable range of high-viscosity-index oils—which is very important in the practical evaluation of these oils as special lubricants. The viscosity index obtained for the oils made by both the improved procedures, namely procedure No. 2 and No. 3, is very much better than in the case of the aromatic type oils even after they have undergone the hydrogenation.

In Table 9 are shown the ordinary tests of two synthetic oils. Oil No. 1 was made by condensing dichloro-kogasin with activated aluminum, while oil No. 2 was made by polymerizing the olefinic fraction 150-200°C. Of especial interest here is that both of these oils show a high oxidation stability, as shown

TABLE 8

Comparison of Lubricants Made by the Three Procedures

Procedure No.	OIL FROM	Specific Gravity d^{25}_{4}	n^{20}/D	Specific Refrac.	Percent C	Percent H	Pole Height	Viscosity Index
I	Trichlorokogasin + Xylol, not hydrogenated	0.935	1.5300	0.566	88.6	11.1	3.6	5
	Same. but hydrogenated	0.894	1.4909	0.549	86.7	13.2	3.2	28
II	Monochlorokogasin	0.857	1.4782	0.558	86.6	13.6	1.58	125
	Dichlorokogasin	0.874	1.4864	0.557	87.4	13.1	1.77	87
III	Polymerisation 150–200° C	0.835	1.4658	0.558	86.0	13.9	2.28	43
	Polymerisation 200–250° C	0.827	1.4618	0.558	85.7	14.2	1.69	120

by the value of the Sligh test which is zero in both cases. The Conradson carbon test is negligible for oil No. 2, but appreciable in the case of oil No. 1, which value approaches quite closely that shown by paraffinic based lubricants. The behavior of both these oils at low temperatures is excellent—as shown by the very low pour test in both cases.

TABLE 9

Analytical Tests of Two Types of Synthetic Lubricants

	Oil No. 1 From Dichlorokogasin	Oil No. 2 From 150–200° C. Fraction
Specific Gravity at 20° C	0.874	0.836
Ref. Index $n^{20}/_{D}$	1.4864	1.4658
Specif. Refraction	0.557	0.558
Flash-Point, Open (°C.)	214	197
Viscosity, °E. at 20° C	39.4	19.4
Viscosity, °E. at 50° C	7.6	4.0
Viscosity Pole Height	1.77	2.31
Viscosity-Index	130	74
Sligh Test (A.S.T.M. Oxidation)	Zero	Zero
Conradson Carbon (percent)	0.62	0.02
Pour-Point (°C.)	−22.5	Below—33

The results of our improved procedure described above show that it is possible to prepare a good grade of lubricating oil from the products of our benzine synthesis—and this procedure can be varied as in our above discussions. The work so far undertaken is only in its first stages and future work will be directed toward producing special type of lubricants not so much from one single fraction of kogasin or by any one limited type of procedure but to make these oils from broader fractions and by methods which we have only alluded to in our present work.

In other words, we intend to do further work with the high-boiling gasoil fraction and also with the olefin portion of our heavier gasoline cuts. When one realizes how broad this type of synthesis can be finally improved upon, it will be seen that it is possible to make these high-grade lubricants from any solid fuel by way of gasification and by way of the kogasin-synthesis. The aim is to prepare these lubricants from the total product derived from our water-gas reaction, without having to reject fractions which here and there appear to be unsuitable.

Summary

1. It was shown that the temperature susceptibility of viscosity of the lubricants made with xylol and chlorinated kogasin could be greatly improved by increasing the contents of paraffinic raw material used in the condensation.

2. We succeeded in preparing lubricating oils by treating a mono- or dichlor-kogasin with activated aluminum metal without the use of aromatic hydrocarbons. These oils show a high viscosity index, and are therefore classified and belong to the typical paraffin-base lubricants.

3. Lubricants were prepared by straight polymerization using aluminum chloride and our synthetic benzine containing appreciable quantities of olefinic material. The viscosity index of these oils depends considerably upon the boiling point of the original fraction used in the polymerization and when a kogasin fraction boiling point 200-250°C. is used, the resultant oil will show a viscosity index typical of paraffinic-base lubricating oils.

4. We have shown the remaining properties of lubricants prepared by various procedures from kogasin. Judging the synthetic oils according to their stability against oxidation, carbon-residue, and pour-point, it is seen that all of these synthetic oils compare favorably with products manufactured from crude petroleum.

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Carbon Dioxide Content of Various Sources

SOURCES	CO_2 Content of Gas Obtained Percent	REMARKS
Natural Wells—Tampico, Mex., Salton Sea, Calif.	95—99	
Heating of Limestone	25—45	Gas evolved is about 50 percent of weight of limestone used. When limestone is treated with acid, the CO_2 yield is about 44%—52% the weight of the stone.
Fermentation Gases	99.5	CO_2 yield is about 5 pounds per gallon of alcohol obtained.
Burning of Coke	15—18	One pound of 90 percent coke will yield 2 pounds CO_2. This is short of the theoretical yield of 3.3 pounds CO_2 per pound of coke. Flue gas from coke-burning may average 15—18 percent CO_2; 80 percent nitrogen (N_2); and small amounts of carbon monoxide (CO); and various hydrocarbons.
Blast Furnace Gas	20—30	Gas also contains 70—80 percent nitrogen and small amounts of carbon monoxide; oxygen and sulfur dioxide.
Fuel Oil	Less than 15	
Natural Gas	10	

Chemistry of Catalytic Hydropolymerization of Acetylene

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AUTHOR'S CONCLUSIONS

1. Acetylene tetramers of branched-chain structure were obtained for the first time as products of partial hydrogenation of acetylene.

2. Among the hydrotrimers of acetylene, the following olefins were found: 1-hexene, 2-hexene, 3-hexene, 3-methyl-1-pentene, 3-methyl-2-pentene, 2-methyl-1-pentene, 2-methyl-2-pentene and 2, 3-dimethyl-2-butene; of diolefins, the following were found: 1, 5-hexadiene, 3-methyl-1, 4-pentadiene and 2-methyl-2, 4-pentadiene. The products of exhaustive hydrogenation of these polymers were found by Raman spectroscopy to contain normal hexane, 3-methylpentane and 2-methylpentane, and by determination of the intensity of the absorption spectrum lines the proportions of these hydrocarbons in the various fractions were determined.

3. Hydrotetramers of acetylene were found to contain 3-ethylhexenes, 2-methylheptenes, 3-methylheptenes and 4-methylheptenes. The approximate content of isooctanes was determined from the octane number of this fraction after its exhaustive hydrogenation.

4. A general outline of hydropolymerization of acetylene over a mixed catalyst (nickel plus zinc chloride) was given, leading to formation of di-, tri- and tetramers.

WHEN acetylene is passed through an aqueous solution of cuprous chloride and ammonium chloride, a linear polymerization of acetylene takes place, forming polymers of exclusively normal structure: $2C_2H_2 \rightarrow CH \equiv CHH = CH_2$; $3C_2H_2 \rightarrow CH_2 = CHC \equiv CCH = CH_2$; $4C_2H_2 \rightarrow CH_2 = CHCH \equiv CHC = CCH = CH_2$. The dimer can be obtained as the main product of the reaction under controlled conditions and serves as the starting material for preparation of chloroprene rubber.[1] Mignonac and St. Anney[2] established that polymerization of acetylene in electrical discharges at low temperatures forms, along with polymers of normal structure, also a branched-chain trimer, namely, 3 methyl-1,4-pentadiene. Polymerization of acetylene at elevated temperatures over heterogeneous catalysts under the conditions investigated heretofore unavoidably formed aromatics and not aliphatic hydrocarbons. These included benzene and higher molecular compounds up to cuprene.[3]

Only hydropolymerization, i.e., polymerization of acetylene in the presence of hydrogen at elevated temperatures over heterogeneous catalysts[4,5,6,7] gave good yields of aliphatic hydrocarbons. It was shown that by varying the proportions of acetylene and hydrogen, products of polymerization can be obtained of varying extent of saturation. However, the structure of the liquid hydrocarbons and the chemistry of their formation have not been established. The present authors showed in a recent study[8] that in the presence of a mixed nickel-zinc chloride catalyst containing a large excess of the second component, this polymerization can be limited to the stage at which the dimer is formed and isobutene can be obtained as the main product of the reaction in yields as high as 70 percent on the acetylene. The by-product consists of 1,3-butadiene and is evidently formed by hydrogenation of vinylacetylene (see equations /1/ and /2/).

Further research on the dimer obtained in the presence of nickel reduced from nickel formate and supported on kaolin revealed that, in addition to 1,3-butadiene and isobutene, 1-butene also frequently is formed, on the basis of which the rupture of the double bond in methyl-cyclopropene, formed as an intermediate product, may be seen to be accompanied by a rupture along a single bond, thus leading to formation of 1-butene. The conditions are being studied at the present time, under which the rupture of the cyclopropene ring occurs predominantly at the double bond, forming isobutene as the chief product. It also is evident that in the cases when carbon is deposited on the catalyst, butenes and ethylene predominate in the gaseous fraction of the reaction products. It is possible that in this case butene is formed mainly as a result of not only hydrogenation of 1,3-butadiene, but also of polymerization of ethylene.

On the basis of the above results, it has been possible in the present study to undertake determination of the structure of the trimers and tetramers of acetylene obtained in the presence of the above-mentioned catalyst, in which the proportion of nickel to zinc chloride was, however, 1:1, or over nickel alone. The enclosed graph reporting the data of distillation and investigation of narrow fractions of the products indicate that the trimer and tetramer fractions are characterized by minimum unsaturation. This graph for hydropolymerization of acetylene has a wave character, hydrogenation occurring mainly on the crests of the waves corresponding to formation of dimers, trimers and tetramers. The olefins formed are not subject to further polymerization under the conditions of the reaction.

Considering that the dimer of acetylene formed by equation /1/ undergoes further linear, as well as cross polymerization as a result of addition of a third molecule of acetylene to it and that the cross dimer formed by the equation /2/ is mostly hydrogenated and undergoes but little further polymerization, the reactions /3/-/7/ may be offered as describing the mode of formation of the trimer. Data are shown in the experimental part confirming the presence among trimers of substantial amounts of 3-methylpentenes and 2-methylpentenes and a very limited amount of 2,3-dimethyl-2-butene, which completely confirmed the above assumptions.

A fourth molecule of acetylene can be added in a criss-cross fashion to the three isomeric dimers, namely, divinylacetylene, dipropargyl and methylpentadiene; a wider diversity and higher content of branched-chain hydrocarbons could be expected in the fraction of hydrotetramers. Schemes similar to those mentioned above should lead to expected formation from divinylacetylene of 3-ethylhexenes and 4-methylheptenes from dipropargyl 2-methylheptenes and 3-methylheptenes and from 3-methylpentadiene 3-methylheptenes and 4-methylheptenes could be shown, which makes it the complexity of the composition of isooctenes and limited number of the individual fractions of C_8 hydrocarbons, the presence of 3-ethylhexenes, 2-methylheptenes, 3-methylheptenes and 4-methylheptenes could be shown, which makes it possible to extend the postulated mechanism of formation of the acetylene polymer isomers also to the fraction of hydrotetramers.

Thus, the total main reaction of formation of isomers by

*This is a complete translation of the original article.

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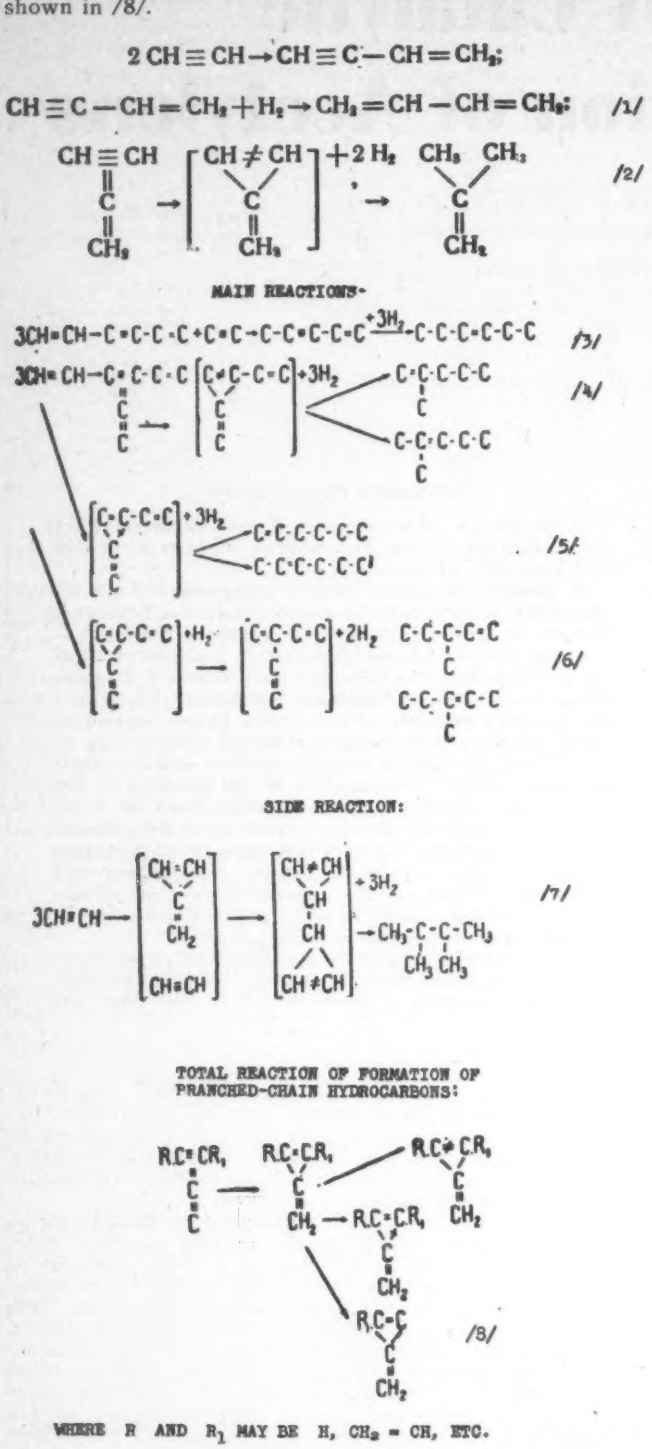
hydropolymerization of acetylene to the stage of dimers, trimers and tetramers can be schematically represented as shown in /8/.



Experimental Part

Figure 1 shows distillation data for the liquid portion of the polymerizate obtained under a 1 m. long 3 cm. diameter Hempel column. Two maxima are revealed by this graph, the higher of the two corresponding to 64-68° and the second, oonsiderably smaller, to the fraction boiling at 118-122°. Further, these maxima correspond to minima of specific gravities of the fractions, which was found to be due to the fact that in the fractions corresponding to the maxima almost exclusively olefins are contained, while those at the minima constitute a mixture of olefins with diolefins. The maximum of specific gravity for the raction 76-78° is due to considerable quantity of benzene present in it, as shown by the reaction of Hofmann and Arnoldi.

The distillation results are shown in more detail in Table 1. The structure of the hydrocarbons composing the product of polymerization was determined by oxidation of the 2° fractions in some cases; in many cases, however, these fractions were combined. The oxidation was carried out in alkaline medium, using a 1 percent solution of potassium permanganate. From 80 g. of the fractions 50-56° and 56-62°, 16 g. neutral products were distilled off with steam. The acids were displaced from the salts and the volatile ones distilled with steam, the non-volatile acids being extracted with ether. Distillation of the ketones showed predominance of acetone and methyl ethyl ketone, which was identified through its semicarbazone melting at 186-187° and 2,4-dinitrophenylhydrazone, melting point 115-116°. Fractional crystallization of 2,4-dinitrophenylhydrazone yielded a fraction with melting point 140°, which corresponds to that of the 2,4-dinitrophenylhydrazone of methyl propyl ketone. The purity of this fraction and of the compound with melting point 115-116° was confirmed by mixing tests. The dinitrophenylhydrazone melting at 140° contained by analysis: C, 49.63 percent; H, 4.95 percent; N, 21.21 percent. Calculated for $C_{11}H_{14}O_4$: C, 49.60 percent; H, 5.3 percent; N, 21.04 percent.

Of the volatile acids of these fractions, only those with 4 and 5 carbon atoms were investigated, in which the presence and structure of branched-chain acids was investigated. These were isolated through the hydroxy acids into which they were converted by direct oxidation of the tertiary carbon atom under the conditions described by R. Meyer[9]. From 13 g. acids, 11 g. crystalline hydroxy acid melting after recrystallization at 65-66° were isolated, the molecular weight of which was 118.37 and the content of silver in its silver salt 48.17 percent. This identified the acid as α-hydroxymethylethylacetic acid, for which a melting point of 66° was reported.[10] Its isomer $(CH_3)_2C(OH)CH_2COOH$ is a syrupy substance.

The non-volatile acids remaining after evaporation of the

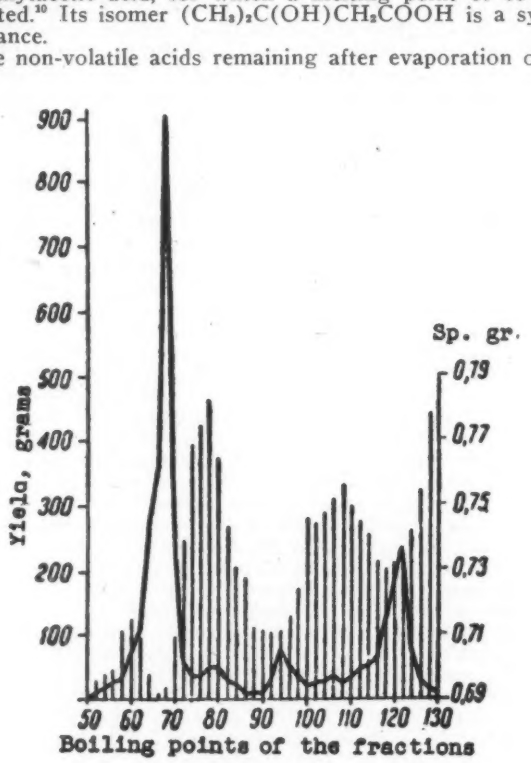


TABLE 1

Boiling Range of the Fractions, °C.	g.	d(20/4)	n(20/D)	Boiling Range of the Fractions, °C.	g.	d(20/4)	n(20/D)
50—52	10	0.69631	1.3918	90—92	28	0.71230	1.4055
52—54	23	0.69801	1.3918	92—94	78	0.71277	1.4060
54—56	29	0.70264	1.3923	94—96	52	0.71593	1.4081
56—58	32	0.71125	1.3926	96—98	32	0.72167	1.4113
58—60	65	0.71438	1.3930	98—100	19	0.73012	1.4148
60—62	112	0.70840	1.3933	100—102	25	0.74603	1.4283
62—64	256	0.69807	1.3948	102—104	27	0.74795	1.4241
64—66	437	0.69132	1.3962	104—106	33	0.75216	1.4259
66—68	910	0.69326	1.3996	106—108	22	0.75689	1.4268
68—70	213	0.70963	1.4091	108—110	30	0.7502	1.4250
70—72	48	0.73900	1.4338	110—112	48	0.7454	1.4230
72—74	33	0.76902	1.4398	112—114	53	0.7415	1.4212
74—76	34	0.77618	1.4431	114—116	65	0.7367	1.4189
76—78	50	0.78320	1.4473	116—118	121	0.7351	1.4179
78—80	47	0.76616	1.4389	118—120	180	0.7350	1.4189
80—82	26	0.74707	1.4275	120—122	236	0.7379	1.4200
82—84	23	0.73035	1.4138	122—124	81	0.7432	1.4227
84—86	5	0.72833	1.4066	124—126	25	0.7543	1.4275
86—88	11	0.71279	1.4063	126—128	12	0.77852	1.4345
88—90	13	0.71223	1.4055	128—130	5	0.77901	1.4360

ether solution constitute a syrupy substance with crystals suspended in it. The latter were removed, pressed on a porous plate and fractionated with the aid of ether. The portion which was sparingly soluble in ether was found to consist of oxalic acid, melting at 187-188°, molecular weight 91.6, containing 70.82 percent silver in its silver salt and giving no depression of the melting point upon being mixed with a sample of anhydrous oxalic acid. The ether-soluble portion consisted of methylmalonic acid, melting point 133-135°, with decomposition, forming upon distillation propionic acid, which was identified as its lead salt, and giving no condensation products with cinnamaldehyde in the presence of quinoline. In addition, the fraction sparingly soluble in ether contained a product crystallizing from alcohol in the form of well-defined crystals with melting point 121°. It formed a phenylhydrazone melting at 162-163° with decomposition. This identified it as mesoxalic acid, for the phenylhydrazone of which a melting point of 160-164° with decomposition was given by Biltz.[11] A phenylhydrazide-phenylhydrazone of mesoxalic acid was prepared melting at 169-170° and containing by analysis 18.71 percent nitrogen.

Mesoxalic acid apparently was formed by oxidation of malonic acid through oxymalonic acid, which points to the presence of 1,5-hexadiene among the diolefins. The syrupy product was found by analysis to be an hydroxyl acid of the composition $C_5H_{10}O_3$, apparently the only liquid hydroxy acid of this composition among the acids obtained by oxidation of branched-chain acids with a tertiary carbon atom, namely, β-hydroxy-isoproplyacetic acid $(CH_3)_2C(OH)CH_2COOH$. These data prove the presence in the fraction 50-58° of the following olefins: 3-methyl-1-pentene, 3-methyl-2-pentene and 2-methyl-1-pentene, as well as diolefins 3-methyl-1,4-pentadiene, 2-methyl-2,4-pentadiene and 1,5-hexadiene.

The fraction 64-66° was oxidized in amount of 160 g. in two portions, the first consisting of 40 g. and the second of 120 g. From the products of oxidation of the first portion, the content of hydrocarbons with a multiple bond in positions 1,2 and 3 were determined. For this purpose the volatile acids were determined by the method of Osborne and coworkers.[12] A preliminary test showed that the content of 5-carbon-atom acids in the fraction analyzed was insignificant; in the fractions 66-68° and 68-70° they were totally absent. The amount of formic acid determined in a separate experiment was found to constitute 1 percent; by the method of Osborne et al[12] 49.9 percent acetic, 4.2 percent propionic and 43.7 percent butyric acids were found. Consequently, the fraction under analysis contained a predominant amount of olefins with double bonds in the position 2.

It is interesting to note that oxidation of the fraction 66-68° gave 39.68 percent acetic acid, 28.3 percent propionic and 29.13 percent butyric acids. Oxidation of the fraction 68-70° gave 57 percent acetic, 27.8 propionic and 16 percent butyric acids. The low content of butyric acid in the last fraction is compensated by the higher yield of the two basic acids, as compared to the fraction 64-66°. Consequently, after the maximum the content of diolefins again increases.

The products of oxidation of the second portion of the fraction 64-66° were combined with similar products of oxidation of the fractions 66-68° and 68-70° Among the neutral products, acetone, methyl ethyl ketone and methyl propyl ketone were identified in this case, similarly to what was found in the case of the fractions 50-56° and 56-62°. However, their relative contents among the ketones was smaller, although the content of methyl propyl ketone rose somewhat. The volatile acids of these fractions were found to possess for the most part a normal structure. The nonvolatile acids included oxalic and methylmalonic acids, however in considerably smaller amounts.

Evidently, the fractions 64-66°, 66-68° and 68-70°, i.e., the basic products of polymerization, contained 3-methylpentene, 2-methylpentene and methylpentadienes. The difference in comparison with the lower fractions consists in the lower content of diolefins and predominance of olefins with double bonds in positions 2 and 3, as well as higher yields of normal olefins, as shown by the lower yield of ketones and almost complete absence of hydroxy acids among the products of oxidation of the volatile acids.

A quantitative determination of straight-chain and branched-chain hydrocarbons in the fractions 58-60, 62-64 and 66-68° was attempted by hydrogenation, followed by determination of the intensity of Raman spectrum lines.*

The fraction 58-60° was found to consist of 40 percent normal hexane and 60 percent of a mixture of 3-methylpentane and 2-methylpentane. Fractions 64-66° and 66-68° contained 67-70 percent normal hexane and only 40-30 percent of the mixture of the above two methylpentanes. The presence of 3-methylpentane was shown by the lines 818(6dd), 753(2) 448(3), 769(2), 749(3) and 733(1). The presence of 2-methylpentane was shown by the lines 446(7) and by comparison of the intensity of the lines 816 and 750. The approximate composition† was established of the fraction 62-64°, which included 70 percent normal hexane, 25 percent 3-methylpentane and 15 percent 2-methylpentane; in a similar manner, for the fraction 68-70°, 70 percent normal hexane, 20 percent methylpentane and 10 percent 2-methylpentane. Close results were obtained for the contents of normal and isohexanes in the fraction 68-70° by investigation of the absorption spectrum in the region close to infra-red.‡ This fraction was found to contain 80 percent normal hexane and 20 percent isohexanes.

Further, the products of hydrogenation of the fractions 60-62° through 68-70° were combined, using 50 cc. of each fraction, and the octane number of this combined 60-70° fraction determined in a Waukesha engine and found to be 44. Considering that the octane number of normal hexane is 25 according to Smittenberg,[13] that of 3-methylpentane 75 and of 2-methylpentane 73, the content of normal hexane in this combined fraction may be calculated to 62 percent and that of the mixture of isohexanes 38 percent.

Thus, the various methods of analysis gave a relatively close picture of the distribution of normal and isohexenes in the products of polymerization. It is further seen that the trimer of acetylene resulting from hydropolymerization (fraction 66-68°) contains for the most part 3-hexene and 2-hexene (50-60 percent) and 3-methyl-2-pentene in mixture with 2-methyl-2-pentene (30-40 percent).

The fractions 70-72° and 72-74° were analyzed for their content of 2,3-dimethyl-2-butene. They were brominated in chloroform under cooling with solid carbon dioxide, and the brominated product, a mixture of oil with crystals, hydrolyzed by boiling with water for 10 hours. The resulting pinacolone was distilled off and identified through its semicarbazone melting at 147° and showed no depression of the melting point with the semicarbazone of known pinacolone.

The fractions 98-100°, 100-102° and 102-104° were oxidized as pointed out above and the products of oxidation tested for trimethylacetic acid, the absence of which and, consequently, also the absence of diisobutene among the products of polymerization was established.

A part of the fraction corresponding to the hydrotetramer boiling at 108-124° was hydrogenated to paraffins and the contents of normal octane and isooctanes approximately calculated from its octane number, which was 37.8. Assuming the octane number of normal octane to be 17 and that of isooctanes arbitrarily as 70, the content of normal octane was calculated to be 37 percent and thus the considerable prevalence of isooctanes established.

The second portion of the same fraction was oxidized under the above-described conditions. The yields of ketones were higher in this case than in oxidation of the fraction of hydrocarbons with 6 carbon atoms. The water-insoluble ketones, 35 g., were fractionated and analyzed, showing that ketones with 6 carbon atoms were predominant:

Fraction	B.p., °C.	g.
1	99-103	6
2	103-120	9
3	120-125	7
4	125-135	13

For the fraction 99-103°, a 2,4-dinitrophenylhydrazone was prepared melting at 134°, remaining unchanged despite numerous recrystallizations. Its mixture with 2,4-dinitrophenylhydrazone of methyl propyl ketone with melting point 141° melted at 138°. The substance melting at 134° was, apparently, a mixture of 2,4-dinitrophenylhydrazone of methyl propyl ketone with the higher-melting 2,4-dinitrophenlhydrazone of diethyl ketone, which could not be separated by recrystallization. Analysis found: C, 49.79 percent; H, 7.31 percent; N, 21.15 percent. Calculated for $C_{11}H_{14}O_4N_4$: C, 49.60 percent; H, 5.30 percent; N, 21.04 percent. At least a portion of the ketones with 6 carbon atoms contained in the higher fractions possessed a methyl group, since it gave bisulfite derivatives and was oxidized with iodine in alkaline medium. These ketones could not be isolated in pure state and identified through their semi-carbazones, which are well soluble in water, or through 2,4-dinitrophenylhydrazones, which had too close solubilities.

A 2,4-dinitrophenylhydrazone was isolated with melting point 116-117°, further recrystallization of which did not change its melting point. A mixed sample of this substance

* This analysis was done by P. A. Bazhulin in the laboratory of Academician G. S. Landsberg at the Physical Institute.

† [? — J.G.T.]

‡ Determined by Yu. A. Korsunovskii in the laboratory of Academician A. N. Terenin at the State Optical Institute.

with 2,4-dinitrophenylhydrazone of methyl ethyl ketone and methyl isopropyl ketone gave a depression of from 20 to 30°. Analysis found: C, 51.61 percent; H, 5.84 percent; N, 19.39 percent. Calculated for $C_{22}H_{16}O_4N_4$: C, 51.48 percent; H, 5.76 percent; N, 19.99 percent.

The volatile acids with 4 carbon atoms and higher were investigated for their contents of branched-chain acids. A crystalline hydroxy acid was obtained by the method of R. Meyer, melting at 80-82°, and a liquid hydroxy acid, mol. weight 130.0, the silver salt of which contained 45.86 percent silver. The molecular weight of $C_6H_{12}O_3$ is 132 and the silver content of its salt 45.2 percent.

Fractional crystallization of the solid hydroxy acids of the composition $C_6H_{12}O_3$ gave, in addition to the product with melting point 80-82°, also lower-melting fractions (melting point 66 and 56°). However, a substance with a constant melting point could not be isolated from them by recrystallization.

The non-volatile acids were distilled under 2-3 mm. pressure into the following fractions: 1, 87-92°; 2, 92-105°; 3, 105-160° and 4, 160-185°. From the first fraction a liquid acid of molecular weight 113.99 was isolated through its calcium salt and its silver salt contained 48.93 percent silver, against calculated for $C_6H_{10}O_5$: mol. weight 114; content of silver in the salt, 48.9 percent.

Similarly, from the fourth fraction an acid of mol. weight 165.56 was isolated through its calcium salt and the silver salt of this acid contained 57.46 percent silver, against the calculated for $C_6H_{10}O_6$: mol. weight, 162; content of silver in its silver salt, 57.44 percent.

Thus, the investigation of the hydroxy acids established the presence of monobasic hydroxy acids of the composition $C_6H_{12}O_3$ and dibasic hydroxy acids $C_6H_{10}O_5$. In addition, dibasic acids found in the products of oxidation of the C_6 hydrocarbons were also found in this case, namely, oxalic, methylmalonic and hydroxymalonic acids.

Among the hydroxy acids of the formula $C_6H_{12}O_3$ resulting from oxidation of acids with a tertiary carbon atom, the following could be present:

$(CH_3CH_2)_2C(OH)COOH$ (1)
$(CH_3)_2C(OH)CH_2CH_2COOH$ (2)
$CH_3CH_2C(CH_3)(OH)CH_2COOH$ (3)
$CH_3CH_2CH_2C(CH_3)(OH)COOH$ (4)
$(CH_3)_2CHC(CH_3)(OH)COOH$ (5)

Dehydration of (1) with melting point 80-82° could give acids $C_6H_{10}O_2$, the solid and the liquid forms of α-ethylcrotonic acid. Dehydration of (2) forms a lactone, the further oxidation of which gives hydroxymethylglutaric acid.[14] Dehydration of (3), the only liquid hydroxy acid of the composition $C_6H_{12}O_3$, yields a solid acid with melting point 46, i.e., methylethylacrylic acid.[15] The acid (4) is a solid substance with melting point 46-47°.[16]

The presence among the products of oxidation of volatile acids of the solid hydroxy acid with melting point 80-82°, and, among the non-volatile, of the liquid unsaturated acid of the composition $C_6H_{10}O_2$, may serve as proof of the presence of the acid (1). The liquid hydroxy acid found among the products of oxidation of the volatile acids established the presence of the acid (3), and the presence of hydroxymethylglutaric acid among the non-volatile acids established that the acid (2) was present. Thus, these hydroxy acids prove the presence in the C_6 fraction of the hydrocarbons: 3-ethylhexenes, 2-methylheptenes and 3-methylheptenes. The acid (4) could not be isolated and identified. However, the presence of 4-methylheptenes is evidently indicated by the products of oxidation containing methyl propyl ketone.

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Caution Continued Vigilance Against Sabotage

CONTINUED vigilance against fire and sabotage was urged on all oil companies July 10, by William R. Boyd, Jr., chairman of the Petroleum Industry War Council.

Boyd's plea was supported by a letter from Undersecretary of War Robert P. Patterson, warning that continuance of dangerous acts of sabotage and the tremendous toll of industrial resources and output taken by fires and accidents refute any assumption that security measures now are less important than in the past.

Recalling that PIWC is one of the only two recipients of the United States Coast Guard Security Shield of Honor in recognition of its contribution to the safety and protection of vital war facilities, Boyd declared "the favorable fire record reported in 1943 by both the PAW and American Petroleum Institute may not be duplicated in 1944 unless adequate fire protection measures are maintained.

"Increased use of sour crude oil, particularly at refineries lacking corrosion-resistant equipment and corrosion-protection experience, could result in fires unless prompt steps are taken to compensate for these unfavorable conditions," he said.

Shortages of experienced personnel and lack of time for the complete training of new workers also may tend to increase accidents and fires, he pointed out

"Unless every known precaution is taken, new and modified refinery processes may suffer some accidents and fires until experience is gained in the efficient operation of equipment geared to wartime standards," he explained. "Severity of fires might likely increase with the decrease in workers' knowledge and experience in fire control and fire extinguishment."

In his letter, addressed to George A. Hill, Jr., chairman of the PIWC Committee on Protection of Petroleum Facilities, Patterson stressed that the military services are depending upon the industry for continued production and delivery.

"Recently the War and Navy Departments announced a revised internal security policy designed to curtail expenditures and to utilize efficiently available manpower commensurate with the present offensive phase of the war," he said.

"The unique importance of the petroleum industry in the prosecution of the war increases the necessity for management to exercise its primary responsibility for the protection of its facilities. I am informed that the revised internal security policy has been misinterpreted by some persons to indicate decreased probability of interference with production by fire, accident and sabotage, and, therefore, a waning interest by the War Department in security measures adopted and vigorously pursued by the petroleum industry. Both assumptions are decidedly unwarranted. The continuance of dangerous acts of sabotage and the tremendous toll of our industrial resources and output taken by fires and accidents refute them.

"The critical shortage of petroleum products demands all available facilities to meet our wartime requirements. We cannot relax our protection efforts lest production and delivery be impaired."

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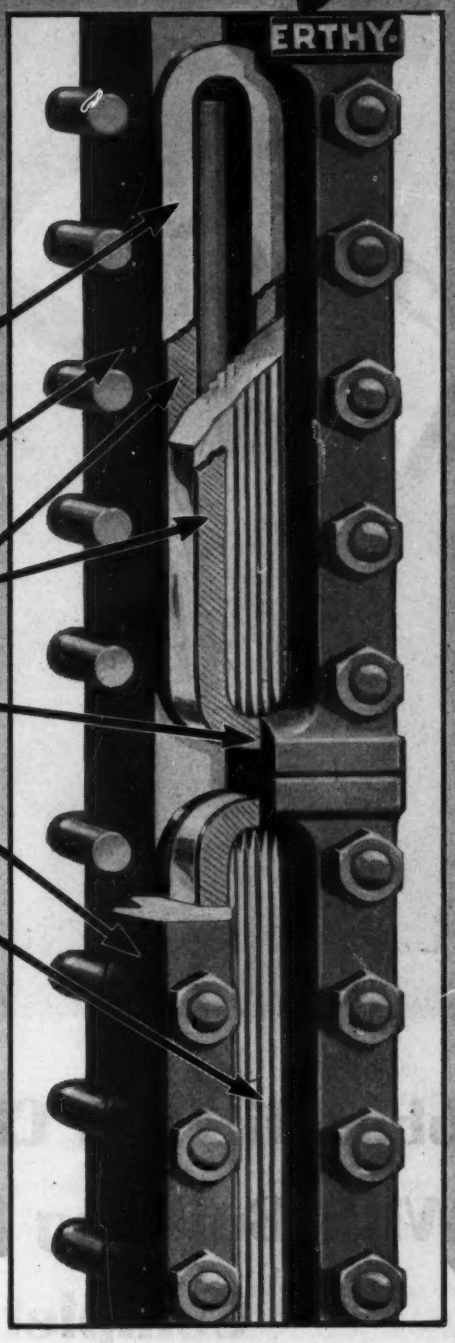

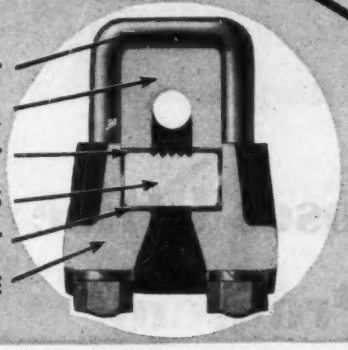

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Rubber Director Closes Office With Building Program Complete

WHEN Colonel Bradley Dewey gets around to the final act of closing out the affairs of the Office of Rubber Director, his action will make the first liquidation of a major war agency. He announced his resignation last month for the reason that the United States is now independent of imported rubber. The problem of the future is one of manufacturing, and that will be handled by the War Production Board.

In proof of what has been accomplished he cited that in the three months that closed June 30, production of synthetic rubber was at the rate of 836,000 long tons per year. In normal years imports of natural rubber into the United States were between 550,000 and 650,000 long tons. His report showed production of 376,087 long tons in the first half of this year. Since the higher production rate was not reached until the end of this period, total production for this year will be 811,000 long tons.

A supply of 118,000 long tons of natural rubber will provide a total of 929,000 tons for the year, in which there is an anticipated need for 883,000 tons.

For the first half of 1945 production of synthetic rubber is estimated at 561,000 long tons, to which a supply of 83,000 long tons of natural rubber will provide 524,000 tons against an indicated requirement for 505,000 tons. The present stockpile of 100,000 long tons of natural rubber will be maintained and by June 30, 1945, there should be a stockpile of 150,000 long tons of synthetic rubber.

When full production is reached next year total output will be 921,500 long tons—780,000 long tons of Buna S, 55,100 long tons of butyl rubber, 67,000 long tons of neoprene and 19,400 tons of Buna N.

Thus far alcohol has contributed more butadiene than has come from the petroleum plants, a condition that will continue through the third quarter of 1944 since seven petroleum-butadiene plants have been shifted to providing butylenes for the aviation-alkylate program over this period. For the fourth quarter of this year, however, the output of butadiene from alcohol will be cut back to around 60,000 tons and the supply from petroleum will be increased to 100,000 tons.

"During the fourth quarter of this year," Dewey explained, "it is not expected that the need for butylene for aviation gasoline will be critical. Obviously with butadiene from alcohol costing about five times as much as that from butylene, only the great need for aviation gasoline justifies any but the minimum use of butadiene from alcohol."

Still Shortage of Tires

Despite the abundance of raw synthetic rubber in his final report, the Rubber Director restated his warning as to finished rubber products, especially tires for civilian use. The major problem is man power, which threatens the production of heavy-duty large truck and bus tires.

"Fewer than 6000 additional workers stand between the shortage and the goal of estimated requirements," he said.

The 22,000,000 passenger tires needed for 1944 will be made in his estimation only if adequate workers and cotton cord are available.

"The availability of sufficient synthetic rubber," he warned, "should not lull the public into false security. The situation in manufacturing is such that recapping tires and using them with extreme care are essential."

"The requirements of the rubber program for the technically-trained men as well as certain skilled workers must continue to come before all but urgent and special manpower demands of the armed forces.

"In short, the problems envisioned by the Baruch committee when it wrote, 'if we fail to secure quickly a large new rubber supply our war effort and our domestic economy both will collapse'

I'm only a bit of dirt

but I can do a lot of damage!

"Let me get into service water or process liquid and see what happens. I can spoil product, cause delay, trouble, damage to equipment.

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"How can you stop me?" With

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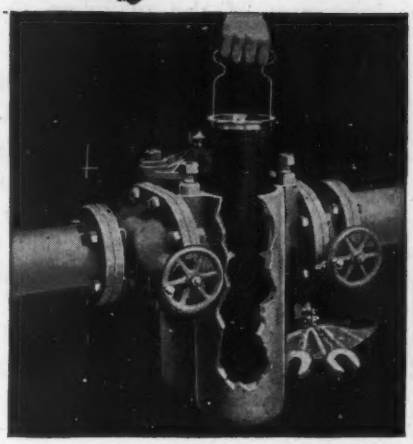

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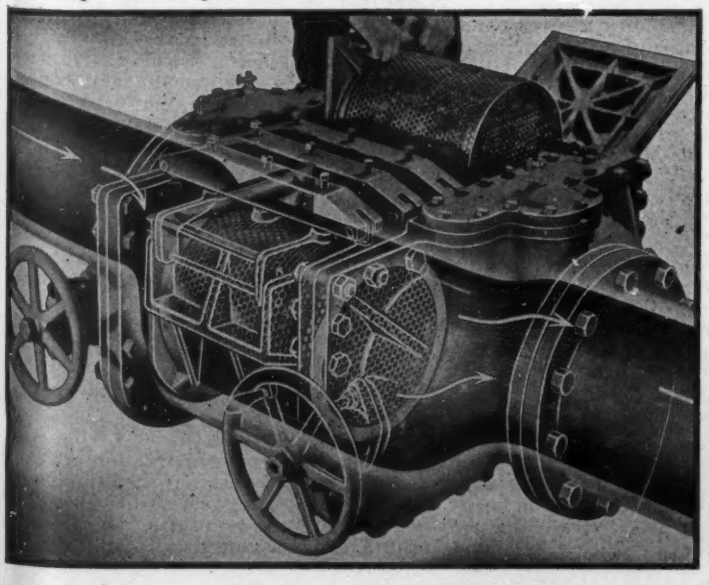

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"I can not see any capitalist planting rubber trees and waiting seven years for them to grow, against a future of unknown labor costs, in competition with chemists who have won every battle they ever entered between synthetics and nature."

This part of the statement he made upon announcing the closing of the Office of Rubber Director is characteristic of the confidence Colonel Bradley Dewey has had in chemical rubber from the inception of the program to replace the natural product.

The picture shows the Rubber Director at his hobby. While on his final inspection tour of plants along the Gulf Coast a professional photographer found an opportunity to record the fact that Bradley Dewey is an avid camera fan.

have been solved but the demands of war are such that it may be many months before sufficient manufactured rubber goods, more particularly heavy-duty truck and bus tires, are available to supply the needs of civilian economy of the United States of America, a country 'geared to rubber'."

Started in 1940

The Office of Rubber Director came into existence following a round of confusion that attended early efforts to get a synthetic rubber program underway because of the threat of war in the Far East.

Rubber Reserve Company, a subsidiary of Reconstruction Finance Corporation, was formed in June, 1940, and for the period that sea lanes were open was an active buyer of natural rubber.

In 1940 the National Advisory Defense Council was concerned as to the supply of natural rubber and a conference of scientists under its auspices resulted in the recommendation that capacity for 100,000 tons of synthetic rubber per year be provided. Standard Oil Company (New Jersey) worked out cooperative agreements with Firestone Tire & Rubber Company and United States Rubber Company in June, 1940. A small plant, 10 tons per day, was completed at the Baton Rouge refinery of Standard Oil Company of Louisiana in 1941. During this period Phillips Petroleum Company and the B. F. Goodrich Company formed Hycar Chemical Company.

Defense Plant Corporation entered into contracts with The B. F. Goodrich Company, Goodyear Tire & Rubber Company, Firestone Tire and Rubber Company and United States Rubber Company for copolyer plants each of 2500 tons annual capacity in May, 1941. Two months later the capacities were increased to 10,000 tons each.

The four rubber companies and Standard Oil Company (New Jersey) set up a pooling agreement December 19, 1941. March 10, 1942 the oil company announced that the Butyl rubber process would be granted royalty free for the war period. March 25, 1942 the oil company signed the consent decree (nolo contendere) because of proceedings brought by the Department of Justice.

In the weeks immediately following the fall of Singapore, February 15, 1942, the synthetic rubber program was expanded first to 120,000 tons per year, then 400,000 tons, next 600,000 tons and finally 800,000 tons, of which 700,000 tons would be Buna S, 60,000 tons of Butyl rubber and 40,000 tons of neoprene.

The period, however, was one of bickering and uncertainty. Although construction had been started in keeping with the contracts let by Defense Plant Corporation in May, 1941, and contracts had been let for production of a limited raw-material program in November, 1941.

Finally the President named a fact-finding committee with Bernard M. Baruch as chairman and two college presidents, James B. Conant of Harvard University and Karl T. Compton, Massachusetts Institute of Technology, as other members. Their findings were made public in September, 1942. In addition to stating clearly what the civilian and military needs in rubber were, it recommended creation of an agency, the Office of Rubber Director, which would give one agency control over development of the program to provide the needs.

William M. Jeffers, president of Union Pacific Railway Company, was selected as director. He accepted the recommendations of the Baruch report as the obligation of his office and set to work to provide the facilities for making the rubber. Although the program in so far as individual plant construction was concerned, changed frequently, the rubber program moved steadily forward under his direction.

Colonel Bradley Dewey was named deputy director and took charge of technical phases of the program.

When the plant-construction program was assured, Jeffers returned to his railroad post and suggested that Dewey be named director, a post he will hold until the agency is closed out.

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Refinery Operations Near Capacity In Meeting Demand

L. J. LOGAN

IN THE half-year just ahead, oil industry operations will further increase to new all-time highs, after having exceeded all previous records in the first 6 months of the year; for the peak demands of war have not yet been reached, although they are being approached.

So sharp has been the increase in demand for petroleum since the European invasion that it now appears as if tightening up of civilian supplies may be the only means of keeping fully abreast of military requirements, in spite of the great war-time expansion of refining capacity and the proportionate stepping up of crude production; although recent statements out of Washington have indicated that current amazing military demand may be expected to ease up somewhat after the critical period of the next few months.

Certainly, there must lie not far ahead either a leveling-out or downturn in military demand or else a further curtailment in use of oils by the public, for the industry is turning out practically all the refined products that its present refining facilities can make, and only limited additional refining capacity is scheduled for completion between now and the end of the year. Furthermore, the industry is producing nearly all the crude that it can, without serious damage to many oil fields, in supplying the current unprecedented refinery requirements for the raw material.

Refining Capacity Ceiling

However, as stated before, the peaks of war time operations have not yet been quite reached, and coming months will bring some further increases in refinery runs and crude production, as additional refining capacity is completed and put to use. Already, numerous oil fields are being produced in excess of scientifically sound rates, and crude storage is being drawn upon heavily, but there is no serious concern over the ability to provide as much crude as present and projected refining facilities can process, at least for the next 6 or 9 months. Refining capacity represents a ceiling on the demand for crude, and although there will be greater difficulty henceforth in holding crude availability up around that ceiling, it is contemplated that this can be achieved under present emergency conditions by further increasing production in fields with or without capacity in excess of "sound" rates, while crude storage evidently has not been drawn down to an irreducible minimum, as demonstrated by continued heavy withdrawals in recent weeks.

Aside from the immediate urgent need for petroleum products for military purposes, the current heavy demand for petroleum reflects also large advance accumulation of fuel oils which actually will not be consumed until next winter. As in other summers, the industry now is producing and running to storage large volumes of fuel oils which will come back out of the tanks late this year and in the first quarter of next year.

It is significant that in planning ahead, by the industry and the government, extreme scarcities are contemplated by the end of the first quarter of 1945. At that time, it was calculated recently, the stocks of all oils (crude and products) will be about 20,000,000 barrels lower than they were at the corresponding time this year and therefore seriously depleted. However, crude stocks lately have had to be drawn upon much more heavily than expected, and in the light of present circumstances, it appears that inventories in general will be critically low before the end of next winter if the war in Europe lasts that long.

What, Comes Spring?

The industry has come, therefore, to the stage of very close figuring in keeping before it a program of supply that will equal indicated demand. The balancing act will not be too hard from now until next spring. Thereafter it might be extremely difficult, should Germany still be fighting.

Various statistics of recent weeks have given evidence of the strain on the industry and its extreme efforts in meeting the near-peak war demands. Crude

Stocks of Crude Petroleum in U. S. by Grades, on July 1, 1941-1944

(Based on Weekly Reports of U. S. Bureau of Mines)

THOUSANDS OF BARRELS

Grade or Origin	STOCKS, JULY 1			
	1941	1942	1943	1944
Pennsylvania Grade	4,265	3,427	2,651	2,666
Other Appalachian	1,446	1,380	1,487	1,477
Lima-Michigan	1,011	1,811	1,120	922
Illinois-Indiana	20,010	13,761	12,475	14,681
Arkansas	2,646	2,865	2,592	2,768
Kansas	8,680	8,118	8,682	8,568
Louisiana	12,376	13,610	14,984	13,369
Northern	4,315	4,683	5,269	3,524
Gulf Coast	8,061	8,927	9,715	9,845
Mississippi	1,573	2,118	1,359	947
New Mexico	7,380	6,683	7,048	6,286
Oklahoma	57,183	46,782	37,784	31,839
Texas	88,683	100,785	104,018	112,438
East Texas	22,494	26,339	21,368	21,838
West Texas	16,515	24,108	25,390	30,956
Gulf Coast	25,399	26,939	30,703	31,413
Other Texas	24,275	23,399	26,557	28,231
Panhandle	.....	.....	5,661	6,253
North	.....	.....	7,052	6,128
South	.....	.....	5,256	6,023
Other	.....	.....	8,588	9,827
Rocky Mountain	15,993	15,924	13,503	8,870
California	35,103	35,666	33,563	21,949
Foreign	2,481	386	157	2,080
Total Gasoline Bearing in U.S.	258,830	253,316	241,423	228,860
Heavy in California	10,657	10,945	10,009	5,975
Total in U.S.	269,487	264,261	251,432	234,835

U. S. Crude Runs to Stills and Percent of Refinery Capacity Used

Runs from Bureau of Mines except May and June, 1944, from A.P.I.; capacities from A.P.I.

THOUSANDS OF BARRELS

State or District	Peak Before U. S. Entry in War Oct. 1941		Low After U. S. Entry in War May, 1942		Current Crude Runs and Use of Refinery Capacity Compared with Year Ago					Total Crude Runs to Stills in First 6 Months of Year		
					June, 1943		June, 1944					
	Runs Daily	Percent of Plant Capacity Used	Runs Daily	Percent of Plant Capacity Used	Runs Daily	Percent of Plant Capacity Used	Runs Daily	Percent of Plant Capacity Used	Percent Change in Runs June '43-'44	1943	1944	Percent Change
East Coast, Texas Inland, Texas Gulf, La. Gulf, Ark. and La. Inland	2,127	93.1	1,498	63.7	1,813	74.2	2,441	96.9	+34.6	304,614	414,996	+36.2
Appalachian	147	88.6	158	91.4	153	86.4	152	85.9	— .7	28,004	27,846	— .6
Ind., Ill., Ky., etc.	734	97.0	735	99.2	712	86.4	774	93.9	+ 8.7	128,872	137,113	+ 6.4
Okla., Kan., Mo.	368	89.1	359	86.1	349	83.9	368	88.0	+ 5.4	61,803	64,096	+ 3.7
Rocky Mountain	94	69.1	91	65.2	104	70.7	115	77.2	+10.6	16,766	19,628	+17.1
California	618	78.5	605	78.3	735	90.0	819	100.3	+11.4	128,429	145,096	+13.0
Total United States	4,088	90.1	3,446	75.2	3,866	80.1	4,670	95.2	+20.8	668,488	808,775	+21.0

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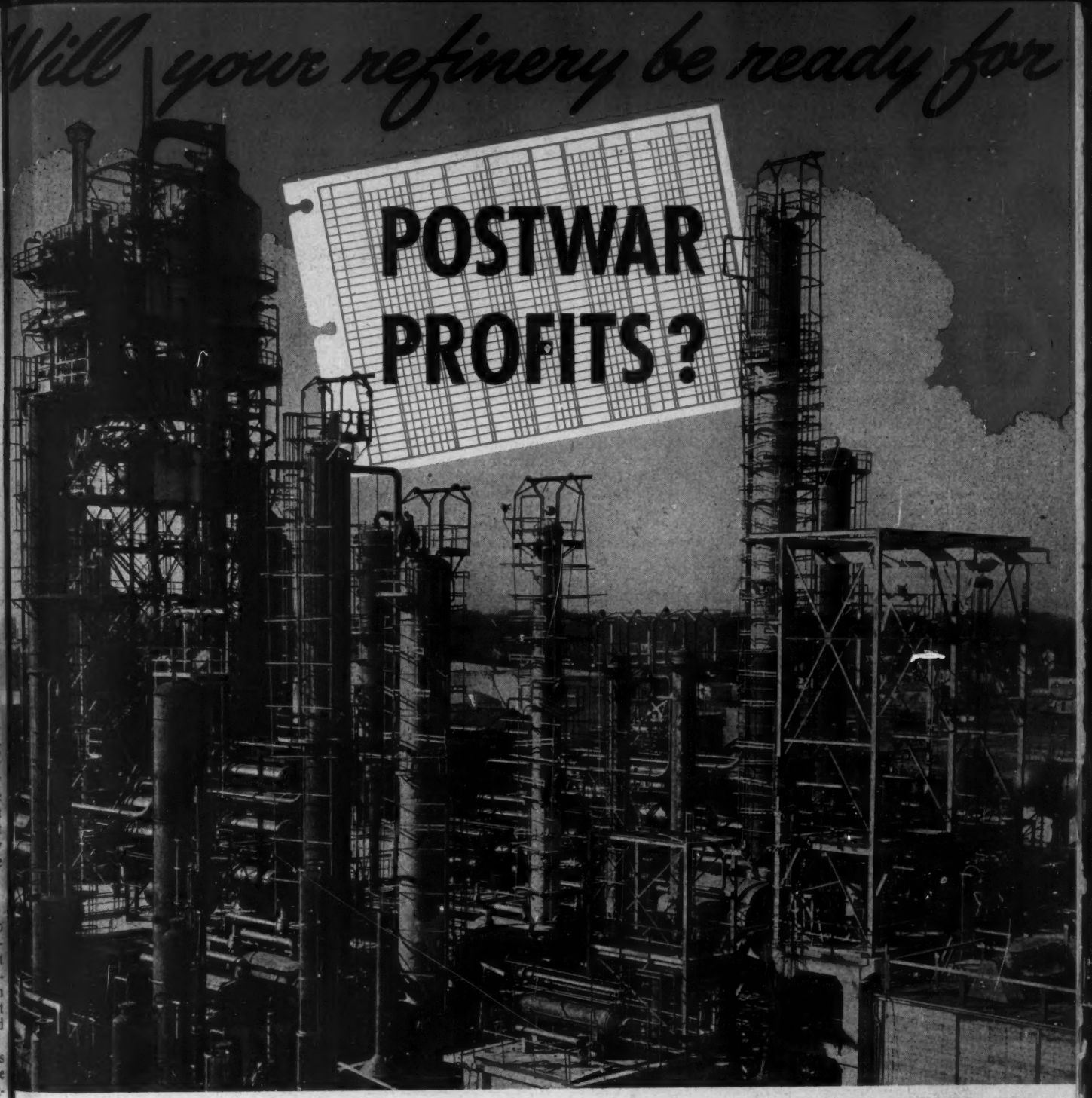

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Stocks of Major Petroleum Products Held by Refining Companies in the United States at End of June, Compared with Year Ago and 2 Years Ago

Stocks at refineries, at bulk terminals, in transit and in pipe lines. Data for 1942 and 1943 from Bureau of Mines monthly reports; for 1944 from weekly reports of American Petroleum Institute.

THOUSANDS OF BARRELS

DISTRICT	FINISHED AND UNFINISHED GASOLINE Stocks End of June			KEROSINE Stocks End of June			GASOIL AND DISTILLATE FUEL Stocks End of June			RESIDUAL FUEL OIL Stocks End of June		
	1942	1943	1944	1942	1943	1944	1942	1943	1944	1942	1943	1944
East Coast, Texas Gulf, La. Gulf, N. La.-Ark., and Inland Texas	41,638	30,714	36,891	6,108	1,965	6,497	15,075	12,958	18,834	16,221	12,391	15,513
Appalachian	2,676	2,230	3,031	315	422	300	527	957	1,461	613	419	498
Indiana, Illinois, Kentucky	16,515	16,108	18,523	1,580	1,565	1,867	3,663	4,876	5,367	3,184	3,179	3,428
Oklahoma, Kansas, Missouri	7,722	6,185	7,486	532	626	511	1,444	1,617	1,328	1,516	1,534	1,421
Rocky Mountain	2,294	1,713	2,440	88	74	79	306	334	336	671	663	661
California	16,672	20,590	15,188	874	585	428	11,486	11,725	8,034	44,136	37,693	24,739
Total United States	87,517	77,540	83,559	9,497	8,237	9,682	32,501	32,467	35,360	66,341	55,879	46,260

runs to stills shot up in the week ended June 17 to 4,752,000 barrels daily, which represented 97 percent of the 4,908,000-barrel potential crude-charging capacity of the nation's materially expanded refining facilities, and the runs have continued subsequently around 95 percent of capacity. Crude oil production climbed to new highs in several successive weeks in June and July in ranging from 4,523,000 to almost 4,600,000 barrels daily. Still it was necessary to draw heavily on crude storage. Within 5 weeks from June 3 to July 8, crude stocks were reduced 8,052,000 barrels, from 234,476,000 to a 22-year low of 226,424,000 barrels, a sustained withdrawal that averaged 230,000 barrels daily. In that 5-weeks period while the 8,000,000-barrel withdrawal of crude was taking place, there occurred an increase of only about 4,000,000 barrels in stocks of major refined products, indicating a net decline of about 4,000,000 barrels in the stocks of all oils. Distillate fuel stocks increased 4,000,000 barrels and residual fuel stocks 3,400,000, but gasoline inventories were reduced about 3,400,000.

Demand Continues Upward

As the latter half of this year opened, demand for petroleum products continued to increase into new high ground, and further stepping up of refinery runs and crude production was under way. For July the Bureau of Mines forecast increases over June in daily average refinery runs and crude production, and still further increases are indicated for August. Total demand for motor fuel in July was forecast by the bureau at 2,184,000 barrels daily, up 31,000 daily over the June forecast and 19 percent higher than actual demand in July, 1943.

In line with Bureau of Mines forecasts, the Petroleum Administration for War certified to the oil-producing states a production rate of 4,907,700 barrels daily of all petroleum liquids for July, an all-time high production rate, representing an increase of 20,600 barrels daily over the previous high reported for June. July was the fourth consecutive month in which the certified production figures exceeded totals certified for the previous month. For August, another new high production rate was clearly indicated. In the July schedule, in spite of the national increase, rates of production certified to the Eastern, Midwestern, and Rocky Mountain states were reduced because of decreased productive capacities as indicated by actual production trends. Those reductions were more than offset by increased rates for the Southwest, principally Texas. For August, likewise, Texas will be expected to make possible the further expansion of national production.

1944 Increase Heaviest

In the first 6 months of 1944, crude oil production was 13.8 percent higher than in the like period of 1943, having averaged 4,461,000 barrels daily against 3,919,000, the former all-time peak for the first 6 months of a year. The crude output in this year's first half was 21 percent greater than that in the like months of 1941, last pre-war year for the United States. The trend of United

Refinery Production of Major Products and Percent Yield from Crude Run, by Districts

Results in June and first 6 months, 1944, compared with those in like periods last year and in 1941, last prewar year for U. S. Table based on U. S. Bureau of Mines statistics, with exception of data for May and June, 1944, estimated with aid of American Petroleum Institute weekly bulletins.

THOUSANDS OF BARRELS

DISTRICT	*Gasoline			Kerosine			Distillate Fuel Oil			Residual Fuel Oil			Lubricants		
	1941	1943	1944	1941	1943	1944	1941	1943	1944	1941	1943	1944	1941	1943	1944
East Coast, Texas Gulf, La. Gulf, North La., Ark., and Inland Texas															
Production, June	26,495	21,675	30,271	3,245	3,332	4,154	8,069	8,284	12,433	13,735	14,746	18,821	1,888	1,580	1,905
(Daily Average)	883	722	1,009	108	111	138	269	276	414	458	491	628	63	53	65
Percent Yield from Crude	43.5	34.5	37.8	5.6	6.1	5.7	14.0	15.2	17.0	23.9	27.1	25.7	3.3	2.9	2.6
Production, Jan.-June	153,678	123,349	169,046	22,866	20,305	25,297	54,301	51,225	71,812	81,697	81,863	109,725	9,630	9,403	10,868
(Daily Average)	849	681	929	126	112	139	300	283	395	451	452	603	53	52	60
Appalachian															
Production, June	2,147	1,767	2,050	242	316	333	422	480	503	658	951	719	565	495	437
(Daily Average)	72	59	68	8	10	11	14	16	17	22	32	24	19	16	14
Percent Yield from Crude	47.2	38.0	44.4	5.4	6.9	7.3	9.4	10.5	11.1	14.7	20.8	15.8	3.3	2.9	2.6
Production, Jan.-June	12,313	10,811	12,072	1,655	2,045	2,037	2,431	3,402	3,238	3,909	5,783	4,598	3,064	2,837	2,682
(Daily Average)	68	60	66	9	11	12	13	19	18	22	32	25	17	16	15
Indiana, Illinois Kentucky															
Production, April	11,728	10,126	11,659	701	1,298	1,078	2,371	2,540	2,837	3,883	4,427	4,657	347	358	418
(Daily Average)	391	338	389	23	43	36	79	85	95	129	148	155	12	12	13
Percent Yield from Crude	52.7	44.7	47.2	3.3	6.1	4.6	11.2	11.9	12.2	18.3	20.7	20.1	1.6	1.7	1.8
Production, Jan.-June	64,250	58,352	69,090	5,832	7,392	6,801	12,466	17,636	17,648	23,164	30,741	28,275	1,930	2,300	2,450
(Daily Average)	355	322	380	32	41	37	69	97	97	128	170	155	11	13	13
Oklahoma, Kansas, Missouri															
Production, June	5,817	5,155	5,478	672	708	687	1,077	1,209	1,708	1,824	2,091	1,884	347	385	387
(Daily Average)	194	172	183	22	24	23	36	40	57	61	70	63	12	13	12
Percent Yield from Crude	50.9	45.2	45.9	6.2	6.8	6.2	10.0	11.5	15.4	16.8	20.0	17.0	3.2	3.7	3.5
Production, Jan.-June	33,344	28,069	32,449	3,860	4,658	4,279	6,516	9,397	9,072	10,718	13,216	11,420	1,884	2,084	2,254
(Daily Average)	184	155	178	21	26	24	36	52	50	59	73	63	10	12	12
Rocky Mountain															
Production, June	1,365	1,348	1,746	82	84	62	231	309	361	582	864	927	9	23	24
(Daily Average)	44	44	58	3	3	2	8	10	12	19	29	31	0.3	0.8	1
Percent Yield from Crude	45.0	42.1	48.5	2.8	2.7	1.8	7.9	9.9	10.5	19.9	27.6	26.9	0.3	0.7	0.7
Production, Jan.-June	8,446	7,764	9,456	433	439	430	1,336	1,780	2,126	3,550	4,850	5,585	96	120	141
(Daily Average)	47	43	52	2	2	2	7	10	11	20	27	31	0.5	0.7	0.8
California															
Production, June	7,584	7,844	9,387	276	322	201	2,527	2,439	2,311	7,573	10,431	11,979	364	331	320
(Daily Average)	253	261	313	9	11	7	84	81	77	252	348	399	12	11	11
Percent Yield from Crude	34.2	30.4	33.1	1.5	1.5	0.8	13.4	11.1	9.4	40.1	47.2	48.7	1.9	1.5	1.3
Production, Jan.-June	41,266	43,946	54,637	1,255	1,811	1,699	14,961	15,420	13,768	43,715	60,927	69,700	1,729	1,695	1,895
(Daily Average)	228	237	300	7	10	9	83	85	76	236	337	383	10	9	10
Total United States															
Production, June	55,136	47,915	60,591	5,218	6,060	6,515	14,697	15,361	20,153	28,255	33,510	38,987	3,530	3,162	3,491
(Daily Average)	1,838	1,597	2,020	174	202	217	490	509	672	942	1,117	1,300	117	105	116
Percent Yield from Crude	44.5	36.9	39.6	4.5	5.2	4.6	12.7	13.2	14.4	24.4	28.9	27.8	3.0	2.7	2.5
Production, Jan.-June	291,968	242,257	346,750	22,866	20,305	40,543	35,901	35,650	117,664	92,011	98,860	229,303	165,753	197,380	20,290
(Daily Average)	1,731	1,499	1,905	198	202	223	508	546	647	916	1,990	1,360	101	102	111

* Production includes straight run, cracked, and natural blended at refineries. Yield indicates percent of crude runs made into straight run and cracked gasoline.

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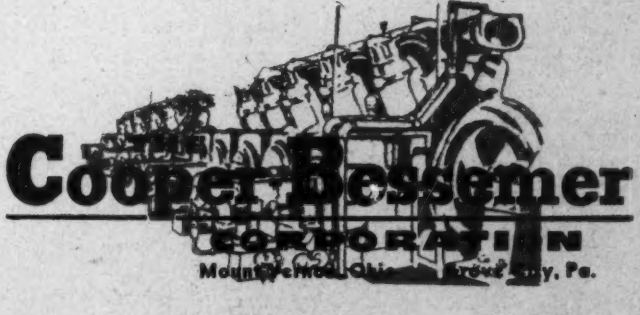

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Production, Changes in Stocks, and Demand for Crude and Products

Bureau of Mines statistics, except data for May and June, 1944, estimated with aid of A.P.I. bulletins.

(Thousands of Barrels)

ITEM	JUNE					FIRST 6 MONTHS				
	1941	1942	1943	1944	Percent Diff. '43-'44	1941	1942	1943	1944	Percent Diff. '43-'44
ALL OILS										
Domestic Production, Total	121,451	115,371	126,554	144,835	+ 14.4	705,237	722,887	753,212	860,200	+ 14.2
(Daily Average)	4,048	3,846	4,218	4,828	+ 14.4	3,896	3,994	4,161	4,726	+ 13.6
Crude Oil	114,854	108,655	119,302	136,810	+ 14.7	666,098	680,902	709,342	811,819	+ 14.4
Natural Gasoline	6,324	6,516	7,252	8,025	+ 10.7	37,403	40,788	43,870	48,381	+ 10.3
Benzol	273	200				1,736	1,197			
Imports, Total	7,427					43,059				
Crude	4,332					22,014				
Refined	3,095					21,045				
Change in Stocks	—2,795	—9,224	—6,001	—2,374		—11,407	—40,728	—13,409	—12,258	
Stocks Beginning of Period	554,665	524,921	489,997	474,170	— 3.2	563,277	556,425	497,940	484,054	— 2.8
Stocks End of Period	551,870	515,697	483,996	471,796	— 2.5	551,870	515,697	483,996	271,796	— 2.5
(Days' Supply)	133	124	110	96	— 12.7	139	122	114	98	— 14.0
Refinable Crude	259,695	251,986	240,601	228,860	— 4.9	259,695	251,986	240,601	228,860	— 4.9
Heavy Crude in Calif.	10,711	10,892	10,064	5,975	— 40.6	10,711	10,892	10,064	5,975	— 40.6
Natural Gasoline	6,235	6,517	5,179	4,100	— 20.8	6,235	6,517	5,179	4,100	— 20.8
Refined Products	275,229	246,302	228,152	232,861	+ 2.1	276,229	246,302	228,302	232,861	+ 2.1
Demand, Excl. of Imports	124,246	124,595	132,555	147,209	+ 11.0	716,644	763,615	766,621	872,458	+ 13.8
(Daily Average)	4,142	4,153	4,419	4,907	+ 11.0	3,959	4,219	4,235	4,794	+ 13.2
Demand, Incl. of Imports	131,673					759,703				
CRUDE OIL—										
Demand by Source—										
Domestic Production	114,854	108,655	119,302	136,810	+ 14.7	666,098	680,902	709,342	811,819	+ 14.4
(Daily Average)	3,828.5	3,621.8	3,977.0	4,560.3	+ 14.7	3,680.1	3,761.9	3,919.0	4,461	+ 13.8
Imports	4,332					22,014				
Change in Stocks, Refinable	—3,036	—3,155	—3,279	—5,590		—5,014	+4,437	+5,712	—12,902	
Stocks, Beginning of Period	262,731	255,142	243,880	234,450		264,709	247,499	234,889	241,762	
Stocks, End of Period	259,695	251,986	240,601	228,860	— 4.9	259,695	251,986	240,601	228,860	— 4.9
(Days' Supply)	66	68	55	48	— 12.7	70	67	62	51	— 17.7
Demand, Excl. of Imports	117,890	111,810	122,581	142,400	+ 7.4	671,112	685,389	703,630	823,721	+ 17.1
(Daily Average)	3,930	3,727	4,419	4,747	+ 7.4	3,708	3,787	3,887	4,526	+ 16.4
Demand, Incl. of Imports	122,222					693,126				
Demand by Use—										
Runs to Stills, Total	115,935	105,376	115,984	140,108	+ 20.8	668,663	652,848	668,488	808,775	+ 21.0
(Daily Average)	2,864	3,512	3,866	4,670	+ 20.8	3,694	3,607	3,692	4,444	+ 20.3
Domestic	111,500	104,756	115,599	137,108	+ 18.6	646,056	639,537	667,363	791,853	+ 18.7
Foreign	4,435	620	385	3,000	+ 679.2	22,607	13,311	1,125	16,922	+ 1404.2
Exports	3,894					15,896				
Transfers to Fuel Oil Stocks, Other Fuel, and Losses	2,923	7,251	6,668	6,300	— 5.5	9,762	34,032	36,420	38,000	+ 4.3
Demand, Excl. of Exports	118,858					678,425				
Demand, Incl. of Exports	122,752	112,627	122,652	146,408	+ 19.4	694,321	686,880	704,918	846,775	+ 20.1
(Daily Average)	4,092	3,754	4,088	4,880	+ 19.4	3,836	3,795	3,895	4,653	+ 19.5
MOTOR FUEL										
Production, Total	57,589	46,045	49,230	62,309	+ 26.6	328,014	307,815	280,906	357,081	+ 27.1
(Daily Average)	1,923	1,535	1,641	2,077	+ 26.6	1,812	1,701	1,552	1,962	+ 26.4
Change in Stocks	—2,635	—7,422	—6,110	—3,191		+4,999	—3,999	—2,970	+6,169	
Stocks, Beginning of Period	91,281	94,029	78,544	78,865	+ .04	83,647	90,596	75,404	69,505	— 7.8
Finished Gasoline	85,425	87,461	73,137	74,665	+ 2.1	77,943	86,159	70,772	64,964	— 8.2
Natural Gasoline	5,856	6,568	5,407	4,200	— 22.3	5,704	4,437	4,632	4,541	— 2.0
Stocks, End of Period	88,646	86,597	72,434	75,674	+ 4.5	88,646	86,597	72,434	75,674	+ 4.5
(Days' Supply)	44	49	39	35	+ 10.3	50	50	46	39	+ 15.2
Finished Gasoline	82,411	80,080	67,255	71,574	+ 6.4	82,411	80,080	67,255	71,574	+ 6.4
Natural Gasoline	6,235	6,517	5,179	4,100	— 20.8	6,235	6,517	5,179	4,100	— 20.8
Demand, (None Imported)	60,224	53,477	55,340	65,500	+ 18.3	323,015	311,814	283,876	350,912	+ 23.6
(Daily Average)	2,007	1,783	1,845	2,183	+ 18.3	1,785	1,723	1,568	1,928	+ 23.0
GASOLINE—Finished										
Production (Straight run, cracked, natural blended)	55,136	44,250	47,915	60,591	+ 26.5	313,297	295,854	271,291	346,750	+ 27.8
(Daily Average)	1,837.9	1,475.0	1,597.2	2,020	+ 26.5	1,730.9	1,634.6	1,498.8	1,905	+ 27.1
Pct. Yield, str. run-cracked	44.5	37.8	36.9	39.6		43.7	41.2	36.2	39.1	
Change in Stocks, Finished	—3,014	—7,381	—5,912	—3,091		+4,468	—6,079	—3,517	+6,610	
Stocks, Beginning of Period	85,425	87,461	73,137	74,665	+ 20.8	77,943	86,159	70,772	64,964	— 8.2
Stocks, End of Period	82,411	80,080	67,225	71,574	+ 6.5	82,411	80,080	67,255	71,574	+ 6.5
(Days' Supply)	43	47	37	34	— 8.1	48	48	44	38	— 13.6
Demand (None Imported)	58,150	51,631	53,827	63,682	+ 18.3	308,529	301,933	274,808	340,140	+ 23.8
(Daily Average)	1,938	1,721	1,794	2,123	+ 18.3	1,706	1,668	1,518	1,869	+ 23.1
KEROSINE										
Production	5,218	4,929	6,060	6,515	+ 7.5	35,901	34,562	36,650	40,543	+ 10.6
(Daily Average)	173.9	164.3	202.0	217	+ 7.5	198.3	191.0	202.5	222	+ 10.1
Percent Yield from Crude	4.5	4.7	5.2	4.6		5.4	5.3	5.4	5.0	
Imports						43				
Change in Stocks	+1,188	+1,064	+1,751	+1,607		+97	—5,018	—1,827	+323	
Stocks, Beginning of Period	8,421	8,433	6,486	8,075	+ 24.5	9,512	14,515	10,064	9,359	— 7.0
Stocks, End of Period	9,609	9,497	8,237	9,682	+ 17.5	9,609	9,497	8,237	9,682	+ 17.5
(Days' Supply)	72	74	57	59	+ 3.5	49	43	39	44	+ 12.8
Demand	4,030	3,865	4,309	4,908	+ 13.9	35,804	39,580	38,477	40,220	+ 4.5
(Daily Average)	134	129	144	164	+ 13.9	198	219	213	221	+ 3.8
DISTILLATE FUEL OIL										
Production	14,697	15,210	15,261	20,153	+ 32.1	92,011	90,958	98,880	117,664	+ 19.0
(Daily Average)	489.9	507.0	508.7	672	+ 32.1	508.4	502.5	546.1	647	+ 18.5
Percent Yield from Crude	12.7	14.4	13.2	14.4		13.8	13.9	14.8	14.5	
Transfers from Crude	210	195	242	263	+ 8.7	1,220	1,174	1,448	1,628	+ 12.4
Imports	211					1,887				
Change in Stocks	+2,885	+2,220	+1,802	+2,935		—4,637	—16,529	—12,473	—6,358	
Stocks, Beginning of Period	35,389	30,281	30,665	32,425	+ 5.7	42,911	49,330	44,940	41,718	— 7.2
Stocks, End of Period	38,274	32,501	32,467	35,360	+ 8.9	38,274	32,501	32,467	35,360	+ 8.9
(Days' Supply)	95	74	71	61	— 14.1	71	54	52	51	— 1.9
Demand, Excl. of Imports	12,022	13,185	13,701	17,481	+ 27.6	97,868	108,661	112,781	125,650	+ 11.4
(Daily Average)	401	440	457	583	+ 27.6	541	600	623	690	+ 10.8
Demand, Incl. of Imports	12,233					99,755				
RESIDUAL FUEL OIL										
Production	28,255	23,352	33,510	38,987	+ 16.3	165,753	173,517	197,380	229,303	+ 16.2
(Daily Average)	941.8	945.1	1,117.0	1,300	+ 16.3	915.8	958.6	1,090.5	1,260	+ 15.5
Percent Yield from Crude	24.4	26.9	28.9	27.8		24.8	25.6	29.5	28.4	
Transfers from Crude	1,070	1,610	1,634	2,400	+ 46.9	4,302	10,193	10,966	14,965	+ 36.5
Imports	2,458					17,021				
Change in Stocks	+730	—2,037	—1,878	+2,130		—8,078	—16,618	—5,904	—2,224	
Stocks, Beginning of Period	79,218	68,388	57,757	44,130	— 23.6	88,026	82,959	61,783	48,484	— 21.5
Stocks, End of Period	79,948	66,341	55,879	46,260	— 17.2	79,948	66,341	55,879	46,260	— 17.2
(Days' Supply)	84	62	45	35	— 22.2	81	60	47	34	— 27.6
Demand, Excl. of Imports	28,595	31,999	37,022	39,257	+ 6.0	178,633	200,328	214,250	246,492	+ 15.0
(Daily Average)	953	1,067	1,234	1,309	+ 6.0	987	1,107	1,184	1,354	+ 14.4
Demand, Incl. of Imports	31,053					195,654				

States crude production during the whole war period has been as follows:

1st 6 Months of Year	Barrels Daily U. S. Crude Prod.	Change from Previous Year
1939	3,444,000	+ 3.4%
1940	3,780,000	+ 9.8%
1941	3,687,000	— 2.5%
1942	3,760,000	+ 2.0%
1943	3,919,000	+ 4.2%
1944	4,461,000	+13.8%

In boosting the nation's crude production about 550,000 barrels a day higher in the first half of this year than in the like months last year, a large part of the responsibility has fallen on Texas, which provided an increase of 511,000 barrels daily in stepping up output to 1,936,000 daily in the first 6 months of 1944 from 1,425,000 daily in the first half of 1943. Sharpest gains among Texas districts occurred in West Texas (up 80 percent), lower Gulf Coast (up 75 percent), upper Gulf Coast (51 percent), Southwest Texas (46 percent). California and the Rocky Mountain states have increased crude production this year, as have Arkansas, South Louisiana, New Mexico, and Kentucky, but those gains have been largely offset by decreased producing ability and production in Illinois, Indiana, Kansas, Oklahoma, North Louisiana, Mississippi, Michigan, and the Appalachian states.

Crude Runs Higher

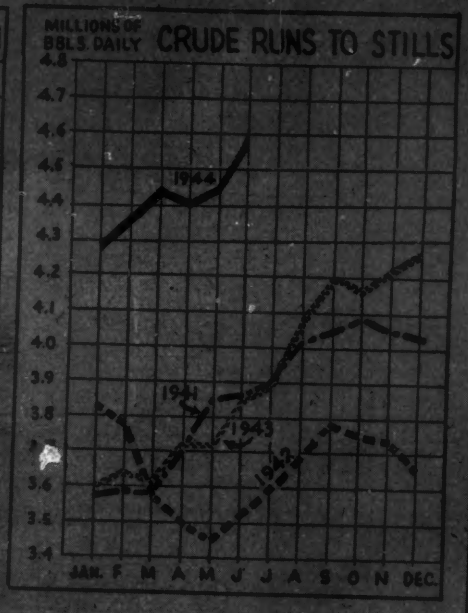
In spite of the record-breaking production of crude this year and some increase in imports, high refinery requirements forced withdrawal of approximately 13,000,000 barrels of crude from storage between January 1 and June 30, an average of 71,000 barrels per day. Having been cut to 228,860,000 barrels at the end of June, the nation's crude stocks were at the lowest level in 22 years, or since 1922, and at the low level inventories were less than needed for desirable flexibility in the industry's operations. With the crude stocks so low, considerable difficulty was being encountered in keeping all refineries supplied with crude in needed grades and volumes, although the PAW organization was facilitating necessary movements of crude to plants through its coordination efforts.

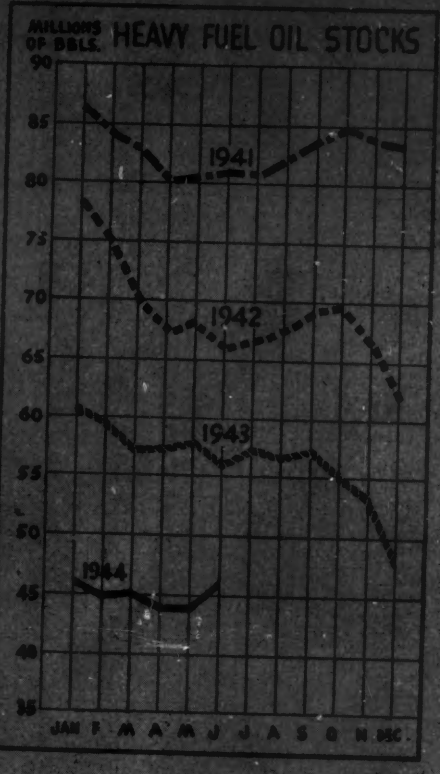
In response to the heavy demands for all products, daily average crude runs to stills were 20 percent higher in the first half of 1944 than in the like period of 1943, in averaging 4,444,000 barrels daily. The trend of crude runs to stills at United States refineries since the beginning of this war has been as indicated herewith.

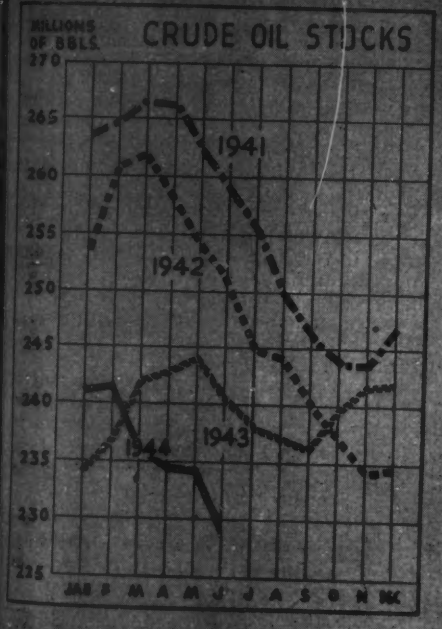
Just as the sharp increase in crude production this year has been accounted for largely by Texas districts, the even sharper increase in refinery throughput of crude has occurred mainly in the plants processing crude from those districts, located in the Southwest and on the East Coast. Increases for the 1944 half-year over the first 6 months of

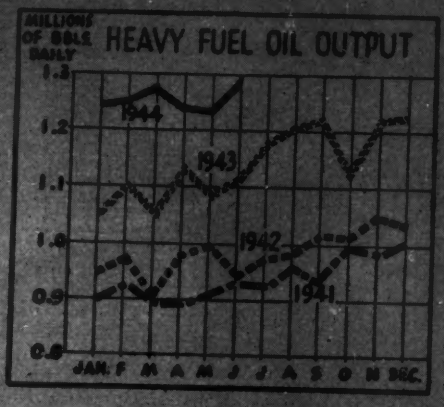
1st 6 Months of Year	Barrels Daily Crude Run to Stills	Change from Previous Year
1939	3,293,000	+ 4.4%
1940	3,546,000	+ 7.7%
1941	3,694,000	+ 4.2%
1942	3,607,000	— 2.4%
1943	3,693,000	+ 2.3%
1944	4,444,000	+20.3%

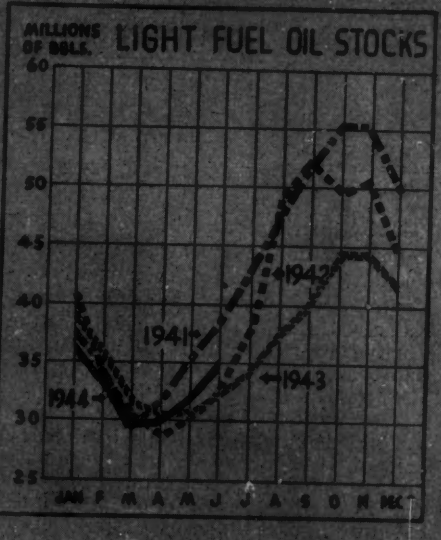
Monthly Activity Trends

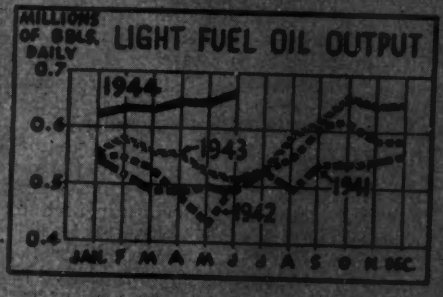


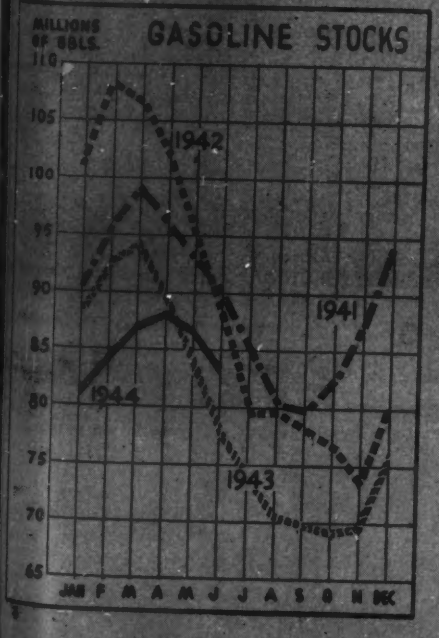


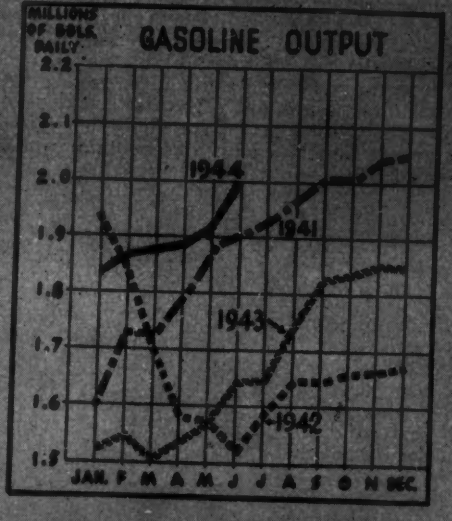


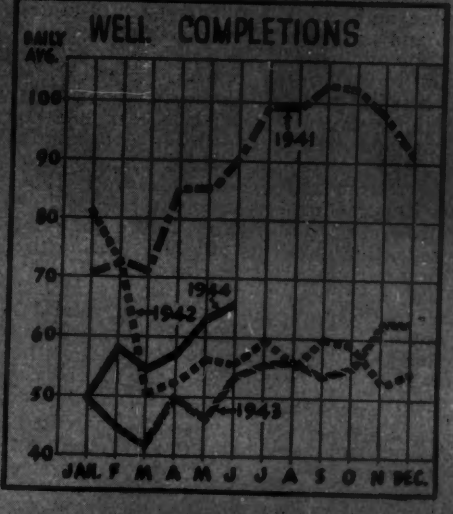












United States Crude Oil Production by States

From U. S. Bureau of Mines, except May and June, 1944, estimated from A.P.I. weekly reports.

THOUSANDS OF BARRELS

State or District	WARTIME FLUCTUATIONS IN DAILY AVERAGE CRUDE OIL PRODUCTION: Peak Before U. S. Entry in War Dec. 1941	Low After U. S. Entry in War April, 1942	JUNE: 1942	1943	1944	Percent Change '43-'44	TOTAL PRODUCTION OF CRUDE OIL: JUNE: 1943	1944	FIRST 6 MONTHS: 1943	1944	Percent Change
Alabama	.....	.....	.....	.....	.1	.....	.....	3	.....	9	.....
Arkansas	74.3	71.6	74.1	76.8	80.4	+ 4.7	2,303	2,411	13,314	14,581	+ 9.5
California	631.9	637.5	650.8	776.0	845.2	+ 8.9	23,279	25,357	139,839	150,969	+ 8.0
San Joaquin Val.	261.3	269.7	267.4	367.1	392.2	+ 6.8	11,012	11,766	65,052	70,445	+ 8.3
Coastal District	87.4	72.3	92.4	108.9	134.4	+ 23.4	3,268	4,032	19,568	23,353	+ 19.3
L. A. Basin	283.3	295.5	291.0	300.0	318.6	+ 6.2	8,999	9,560	55,219	57,171	+ 3.5
Colorado	6.1	5.7	6.0	6.3	8.2	+ 30.2	189	247	1,085	1,371	+ 26.3
Florida	.....	.....	.....	.....	.05	.....	.....	2	.....	9	.....
Illinois	397.8	301.6	284.0	222.7	206.7	— 7.2	6,680	6,202	41,919	38,977	— 7.0
Indiana	18.6	19.8	19.6	14.5	12.4	— 14.5	435	374	2,694	2,499	— 7.2
Kansas	256.7	249.8	271.4	288.2	276.7	— 4.0	8,646	8,300	54,712	49,555	— 9.4
Kentucky	12.7	11.9	11.8	22.1	21.4	— 3.2	664	642	3,467	4,028	+ 16.2
Louisiana	347.4	306.8	304.7	323.0	362.0	+ 12.1	9,690	10,861	59,897	64,579	+ 7.8
North Louisiana	139.2	75.3	82.6	76.4	73.6	— 3.7	2,292	2,209	14,230	12,605	— 11.4
South Louisiana	208.1	231.5	222.1	246.6	288.4	+ 16.9	7,398	8,653	45,667	51,974	+ 13.8
Michigan	56.8	62.5	66.2	57.2	49.9	— 12.8	1,717	1,496	10,566	9,396	— 11.1
Mississippi	70.5	96.2	84.4	53.7	43.7	— 18.6	1,612	1,310	9,940	7,713	— 22.4
Missouri	.1	.1	.1	.1	.1	.....	3	3	18	18	.....
Montana	22.0	22.0	23.2	21.9	21.4	— 2.3	656	644	3,737	4,195	+ 12.3
Nebraska	5.1	3.9	3.8	1.9	1.0	— 47.4	56	29	378	199	— 47.4
New Mexico	112.2	67.3	68.6	105.0	108.1	+ 3.0	3,151	3,243	18,036	20,399	+ 13.1
New York	15.1	15.3	15.5	14.6	13.9	— 4.8	436	418	2,555	2,365	— 7.4
Ohio	9.9	10.6	10.7	9.5	6.0	— 36.8	285	179	1,626	1,405	— 13.6
Oklahoma	427.6	389.6	394.3	339.0	332.8	— 1.8	10,169	9,986	61,812	60,573	— 2.0
Pennsylvania	49.3	52.7	52.0	45.6	40.6	— 11.0	1,368	1,219	8,089	7,300	— 9.8
Tennessee	.1	.1	.1	.....	.....	.....	1	1	5	6	+ 20.0
Texas	1,532.3	1,081.0	*1,179.3	*1,498.4	2,034.1	+ 35.8	*44,953	61,022	*257,977	*352,279	+ 36.6
E. Texas Field	386.2	225.4	347.3	335.2	360.8	+ 7.6	10,056	10,823	59,171	66,959	+ 13.2
Other E. Texas	86.1	77.7	88.6	123.6	144.6	+ 17.0	3,707	4,337	19,508	22,930	+ 17.5
North Texas	137.1	130.5	148.1	131.8	149.3	+ 13.3	3,954	4,478	24,207	26,194	+ 8.2
West Texas	303.4	185.8	212.8	228.8	446.8	+ 95.3	6,864	13,405	39,018	70,257	+ 80.1
Panhandle	92.1	83.5	92.5	90.2	92.1	+ 2.1	2,705	2,763	16,149	17,174	+ 6.3
Gulf, Upper	303.2	227.5	252.4	379.9	528.0	+ 39.0	11,396	15,839	62,442	94,571	+ 51.4
Gulf, Lower	126.9	82.6	85.8	134.3	215.5	+ 60.5	4,028	6,466	20,977	36,645	+ 74.7
Southwest Texas	78.2	48.0	43.9	57.2	77.4	+ 35.1	1,718	2,322	9,550	13,942	+ 45.9
South Central	20.1	19.0	15.6	16.5	19.7	+ 19.4	495	591	3,036	3,606	+ 18.8
Utah	.....	.....	.....	.....	.....	.....	1	.....	3	.....	.....
West Virginia	9.8	10.4	10.2	9.9	8.4	— 15.1	298	253	1,707	1,555	— 8.9
Wyoming	82.2	85.4	89.0	90.3	87.0	— 3.7	2,710	2,611	15,965	15,813	— .9
Total U. S.	4,138.5	3,501.8	3,619.8	3,976.7	4,560	+ 14.7	119,302	136,810	709,342	811,819	+ 14.4

* Data by districts on A.P.I. Basis, and therefore do not agree exactly with Texas total.

1943, by districts, have been as follows: 36 percent for the Southwest-East Coast districts, 6 percent for Indiana-Illinois-Kentucky, 4 percent for Oklahoma-Kansas-Missouri, 17 percent for the Rocky Mountains, and 13 percent for California.

Demand Increases

Total demand for all oils in the first half of 1944 showed an extraordinary increase of more than 13 percent over that in the like period of 1943, as indicated by figures on domestic production of crude and natural gasoline and changes in stocks of crude, natural gasoline, and refined products, such total demand having averaged 4,794,000 barrels daily against 4,235,000, without considering imports in either year. Actually, imports are generally known to have been higher this year than last year, and so the gain really has been somewhat more than 13 percent, which is based on the 14 percent increase in crude production, a 10 percent increase in natural gasoline production, and practically the same net reduction in stocks of all oils during the first 6 months this year as the 13,409,000-barrel reduction in the like period last year. Figured in the same way, total demand (not considering imports) averaged 4,907,000 barrels daily for the month of June, an increase of 11 percent over June of last year.

As indicated previously, fulfillment of the enormous demand was achieved not only by sharply increased domestic production and larger imports but also by continued important withdrawals from storage, which finally have left inventories unsatisfactorily low.

Although the 13 percent increase in the total demand for all oils for the first 6 months of this year has resulted from important gains for all of the principal petroleum products, the sharpness of the increase reflects particularly the 23 percent rise in demand for motor fuel, to 1,928,000 barrels daily from 1,568,000 daily in the first half of 1943. For the month of June, this demand was up to 2,183,000 barrels daily, or 18 percent above June last year. The phenomenally great demand for motor fuel has occurred in spite of rationing, and it reflects heavy military requirements of automotive as well as aviation grades of gasoline. In supplying this great demand, there has been a swing-back to larger refinery yields of gasoline from crude, following a protracted period in which yields were held down to provide more fuel oils. The gasoline yield for all U. S. refineries in the January-June period was back up to 39.1 percent in 1944 compared with 36.2 in 1943 and 41.2 in 1941. Yields by districts appear in an accompanying table. With both runs to stills and gasoline yields increased, U. S. production of motor fuel was 26 percent higher in the first half of this year than in the like period last year, and all refining districts except the Appalachian and Oklahoma-Kansas-Missouri districts exceeded the former record January-June production that was established in 1941. Stocks of motor fuel so far have been kept at adequate levels. At the end of June, 1944, they were 3,000,000 barrels or 4.5 percent higher than one year previously, although with demand so much higher, they represented only 39 days' supply against 46, on the basis of daily average demand in the first 6 months of each of the years.

Residual fuel oil, next most important product by volume, also showed a further large increase in demand, which was 14 percent greater than in 1943 for the first 6 months, not considering imports, which presumably were also higher. For the half-year the demand averaged 1,354,000 barrels daily, against 1,184,000 in the first 6 months of 1943, as calculated in one of the tables herewith. Conversely to the trend for gasoline, refinery yield of residual fuel has been cut back somewhat from former abnormally high levels but still remains above normal. It averaged 28.4 percent for the January-June period this year, compared with 29.5 in 1943 and 24.8 in 1941. Nevertheless, with crude runs high, production of residual was 15.5 percent greater in this year's first half than in the first 6 months of 1943. This national increase occurred although California and Oklahoma-Kansas-Missouri showed decreases from last year. In all other refining districts, residual porduction exceeded all previous records for the first 6 months. Following former steady diminution, stocks of residual fuel oil have been fairly well stabilized this year. They were only about 2,000,000 barrels lower on June 30 than on January 1, in totaling 46,260,000 barrels. That quantity represented, however, only 34 days' supply on the basis of daily average demand in January-June, 1944, whereas stocks of 55,879,000 barrels on June, 1943, were euqivalent to 47 days' supply. Stocks in California account for that decrease from a year ago, those east of California being in the aggregate about 3,500,000 barrels above a year ago, with this gain principally in the East Coast-Southwest districts.

Distillate fuel oil demand showed an increase of about 11 percent for the first 6 months, in spite of rationing and a comparatively mild winter. But production was about 19 percent above 1943, with refinery yield (14.5 percent) about unchanged for the larger runs to stills; and stocks on June 30, 1944, totaled 35,360,000 barrels against 32,467,000 a year previously. This increase was proportional to the expansion of demand, and the June, 1944, stocks represented 51 days' supply.

Kerosine demand was up only about 4 percent for the first half of this year, and although yield was lowered to 5.0 percent from 5.4 in 1943, production showed a 10 percent increase, with the result that stocks increased 323,000 barrels during the half-year in contrast with a decrease of 1,827,000 barrels in the like period last year. The inventories of 40,220,000 barrels on June 30, 1944, exceeded those a year previously by nearly 1,500,000 barrels and represented 44 days' supply against 39.

Lubricating oils, like other products, have been in greater demand this year than ever before, and production averaged 111,000 barrels daily in the first 6 months of this year, an increase of about 9 percent over the 102,000 barrels per day for the first half of 1943.

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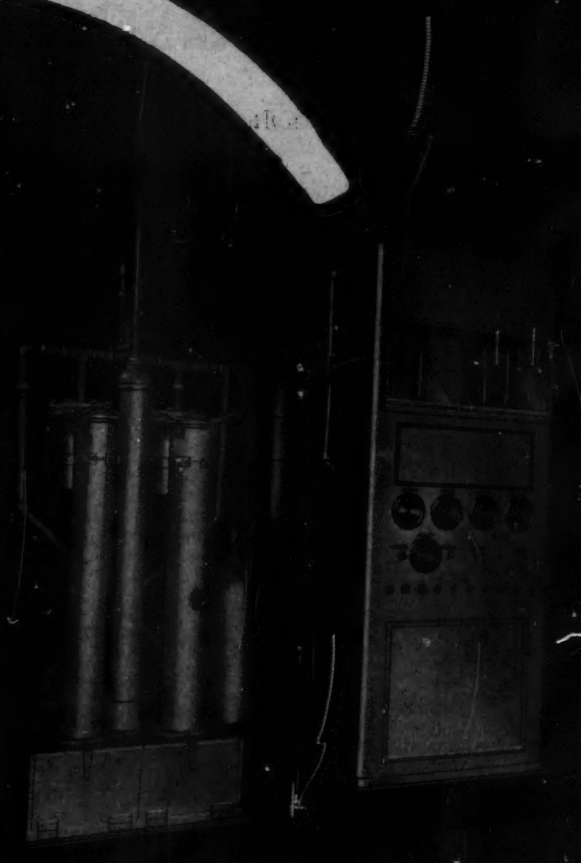

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Coal As an Auxiliary Source Of Gasoline Supply*

HORACE C. PORTER, Consulting Chemical Engineer

THE present widespread interest in the question of our being able to meet increasing demands for motor and aviation fuel from native petroleum sources makes it advisable to study carefully the available alternate sources.

Discussions on the subject of future oil supply have been frequent before technical societies, in congressional hearings, in the public press, and at international conferences. Bills are pending in Congress for government participation in the development of oil supply abroad and have been enacted for government pilot-plant experimentation on coal-conversion processes. Testimony on this and related matters was given by the late W. S. Farish, president, Standard Oil Company (New Jersey), at hearings before a subcommittee of the Mines and Mining Committee, U. S. House of Representatives, July 15, 1942[1]. Testimony with detailed estimates of comparative costs, yields, steel requirements, etc., was given by Executive Vice President R. P. Russell, Standard Oil Development Company, before the Subcommittee on War Minerals of the Public Lands and Surveys Committee, U. S. Senate, August 3, 1943[2].

Considering the Fischer-Tropsch process for converting coal into water gas and thence into gasoline, a method used in Germany to supply a large proportion of its motor fuel (analyzed in the testimony cited above as to probable costs and yields along with comparative figures on the same process applied to natural gas), we need to emphasize the inadequacy of our natural gas supply in meeting a petroleum or gasoline shortage. This point is not touched upon plainly in recent presentations of these matters.

European studies, quoted and further developed by Russell, show that by this process the production of 1 barrel of gasoline will require 11,950 cubic feet of natural gas. In making only one tenth of the 600,000,000 barrels of gasoline used in this country in 1940, this process would consume 719 billion cubic feet of natural gas, or 27 percent of all that marketed in 1940 (24 percent of the gas marketed in 1942). Unless production could be boosted, in equal or nearly equal measure, which is doubtful, in view of the gradual exhaustion of many fields as admitted by natural gas producers, such a drain on production would cripple the carbon-black industry, seriously affect industrial activities, and endanger home heating in many parts of the country where coal supplies are inadequate.

On the other hand, 0.8 ton of coal is required by this process to make a barrel of gasoline. A 10 percent boost in gasoline production would require 48,000,000 tons of coal, only 8.3 percent of our 1942 production. This amount is scarcely one third of the average excess of existing mine capacity over yearly production during 1925-40[3]. Low-sulfur coals are preferable for this process and while their occurence is limited, production of this type of coal can be extended, in both the Appalachian and western fields, to meet easily a gradually developing demand. If the whole of the 1940 gasoline demand had been met by coal conversion, the total demands would have required 180 percent of the actual coal production. It has been estimated, however, that even at this rate of consumption, our coal reserves would last 1,000 years.

As to comparative costs, using the Fischer process, the European estimates as developed by Russell would indicate the following:

	Cost per Gallon of Gasoline (not including depreciation)
Using coal, at $2.25-2.35 per ton	$0.147
Using natural gas, at $0.05 per thousand cubic feet	0.06
Modern oil refinery, crude at $1.20	0.051
Modern oil refinery, crude at $2.00	0.083

From these estimates, it appears that the differential cost between Fischer process gasoline and gasoline at the modern refinery with crude at $2.00 per barrel would be 6.4 cents per gallon. If 10 percent of our requirements were made by the Fischer-Tropsch process, this increase, if absorbed in the total output, would add only 0.65 cent to the consumer's 22 to 23 cent retail price.

However, there are cost factors inherent in the use of coal that act to reduce this differential. Transportation cost is one of them. In the retail price of gasoline, perhaps 2 to 4 cents per gallon is charged to freight on either crude or finished product. As the bulk of petroleum production is now west of the Mississippi, the crude must come long distances to the Eastern market. In the case of coal conversion, plants at the mines would be close to points of gasoline consumption, since the coal fields that could be used are well distributed throughout the country, and the best are in the East. Freight cost on gasoline would in many localities be cut under that prevailing by perhaps 1 cent per gallon or more.

A large cost item in the coal Fischer process as estimated by Russell in investment. This would amount to about 5 cents per gallon if the carrying cost of the investment is taken at 10 percent annually. For this estimate, a large number of plants, each converting 3000 tons of coal per day, were used as a basis. It is likely that experience will show a saving over this plant-investment cost through use at the mines of large by-product coking plants approaching in size that of the Carnegie Steel Company at Clairton, Pennsylvania (33,000 tons of coal per day). By making coke at such plants, on a coal cost of $2.35 per ton, and with low fixed charges and operating costs secured by both the size of plant and high-load-factor in operation, cost of the coke into the water-gas conversion sets and of the water gas into the Fischer synthesis could be cut, thus still further reducing Russell's estimate of the differential between cost of coal-conversion gasoline and present costs from petroleum. By-product coal gas from the ovens would probably have ready sale, through existing pipe lines, to replace natural gas. By-product tars and light oils could be hydrogenated or otherwise processed.

A further important feature of such a plan of development of coal-conversion gasoline in large mine-mouth plants, provided it is put under way not too long after the close of the war, is that much of the large surplus government-owned war-plant investment could be utilized, and the equipment in many such plants is of the right type and favorably located.

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[1] Frolich, P. K., *Ind. Eng. Chem.*, 35, 1131-8 (1943).
[2] Russell, R. P., *Am. Gas. Assoc. Monthly*, 26, 87-92 (Feb. 1944).
[3] U. S. Bur. Mines, Minerals Yearbook for 1940, p. 768.

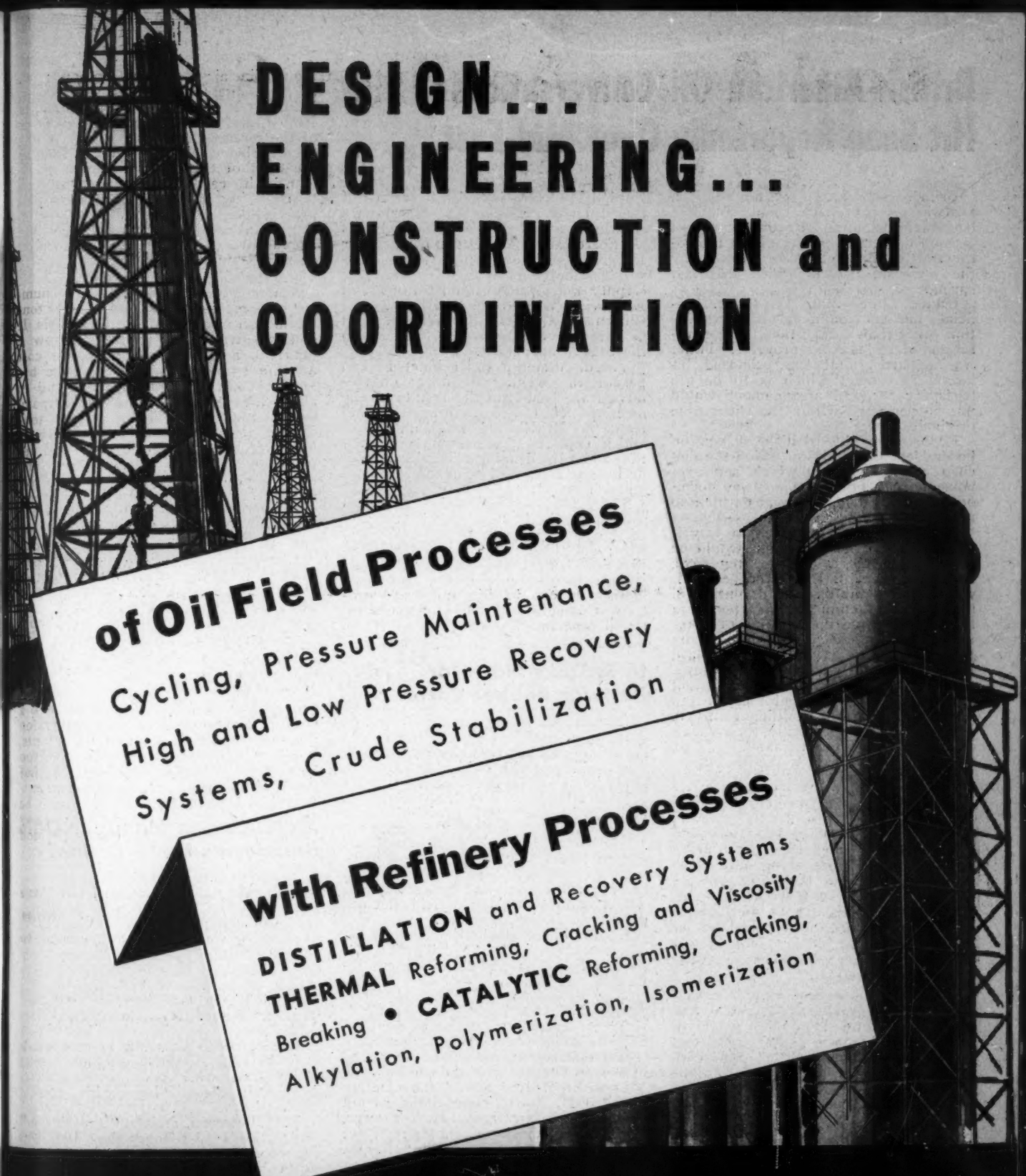
*Chemical and Engineering News, 22, 11, p. 904, June 10, 1944.

Sinclair Advancing Plans For Venezuelan Refinery

Sinclair Oil Corporation, New York, recently announced formation of two Venezuelan subsidiaries and contemplates the building of a 35,000-barrel refinery on a site already owned near the Puerta de la Cruz terminal of the Venezuelan Oil Corporation. The pipe line from Santa Barbara to the terminal is now being increased from a capacity of 45,000 to 75,000 barrels a day.

Due to war demand, it is intended initially to operate the refinery for the production of 80-octane gasoline, Navy diesel and fuel oil. In addition to crude and cracking stills, acid plants and an electric generating station, the plans include housing for employes, a hospital and school.

The two subsidiaries organized under the laws of Venezuela are Sinclair Oil Company of Venezuela and Sinclair Refining Company of Venezuela.



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British-American Oil Conversations Hit Snag Reportedly Over Mid-East

British-American discussions of a postwar oil pact have been prolonged beyond anticipations by differences of opinion on certain phases of the memorandum of understanding drafted by the technical groups which met last spring.

United States State Department officials had no comment on the situation other than to say that the conversations were "making progress," but it was apparent that the proposed bilateral agreement which is to be the basis for a world arrangement would not be perfected within the short time originally set.

Reportedly, the British delegation had raised the points on which the discussions slowed down which, again reportedly, concerned the postwar development of Middle East areas which so far have not been exploited.

As the conference opened in July it was predicted the agreement would be perfected within a week or ten days, but at the end of the latter period it was admitted the discussions were still going on, although it was then said they should wind up in a day or two.

The British delegation, headed by Lord Beaverbrook, includes Richard Law, minister of state; Geoffrey Lloyd, chairman of the oil control board, and Ralph Assheton, financial secretary to the treasury, with Sir William Brown, who headed the technical group which came to Washington last April, as chief technical adviser to the delegation.

The corresponding American delegation is headed by Secretary of State Cordell Hull, and includes Secretary of the Interior Harold L. Ickes, vice chairman; Secretary of the Navy James V. Forrestal; Under-Secretary of War Robert P. Patterson; Foreign Economic Administrator Leo T. Crowley; Deputy Petroleum Administrator Ralph K. Davies; War Production Board Vice Chairman Charles E. Wilson, and Charles Rayner, petroleum adviser to the State Department.

The discussions, on a cabinet level to permit the writing of formal agreements, are based on the results of the meetings held two months ago between the British and American groups which explored the postwar oil situation and agreed upon principles for orderly marketing and economic development of world resources.

The exploratory discussions went into problems affecting the operations abroad of the American and British oil industries; questions relating to oil production, particularly in the Middle East where they involved the proposed Trans-Arabian pipe line and Iraq Petroleum Company's project for an additional pipe line from Kirkuk to Haifa.

BASIL HOPPER

As vice president of Union Oil Company Basil Hopper will continue to direct the department of manufacturing. He was elected to this position in June, after serving as manager of the manufacturing department. Hopper has been with Union Oil Company since 1923, after graduating from California Institute of Technology.

U. S. Talks Plans for Postwar Rubber Cartel

Representatives of the State Department of the United States and of the American Rubber Industry are in London to discuss with British and Netherlands interests the desirability of establishing a committee to keep the crude and synthetic rubber situation under survey with a view of eventual consideration of postwar problems affecting rubber.

There has been talk in Washington of government plans for cartels to which nations and not individual companies would be signatory.

Neither oil or alcohol industries have representation with the delegation, although the department's statement indicates synthetic rubber will be discussed. However, officials said interested oil companies will be kept advised of developments, and to this end officials of the department met with representatives of companies interested in the production of butadiene July 19.

Those invited to attend the meeting included M. J. Rathbone, Standard Oil Company of New Jersey; H. A. Trawer, Phillips Petroleum Company; J. F. Drake, Gulf Oil Corporation; E. W. Isom, Sinclair Refining Company; W. S. S. Rodgers, The Texas Company; William R. Boyd, Jr., chairman of PIWC, and W. D. Crampton, director of the foreign division, PAW.

In rubber circles, synthetic is seen as the crux of the postwar rubber problem, with heavy United States production offering severe competition to natural rubber if the plantations now in the hands of the Japanese have not been destroyed, and as a barrier to their re-establishment if they have.

By the end of the war, a synthetic production of 1,100,000 tons a year is scheduled for this country and synthetic also is produced in Germany and Russia—giving, as estimated in some quarters, a world rubber potential of anywhere up to 2,700,000 tons, against which is figured a postwar demand of about 1,600,000 tons. That 1,100,000-ton surplus may be the fly in the ointment of the international considerations. Whether it actually will exist will depend upon the condition of the producing areas when the Japanese are driven out.

Rubber company representatives say that if the plantations are in good shape and synthetic rubber costs have been brought down to the level of the natural product, a serious problem will arise as to the respective place of each in the postwar set-up. On the other hand, if the plantations have been destroyed or are badly deteriorated, which is most likely, and synthetic costs are down, the question will arise as to how the natural industry can be revived. More than half of the natural production in the past has been from state-controlled plantations with high production costs, which might find it difficult to get reestablished in competition with low-priced synthetic. (See page 126).

CORRECTION

In the June PETROLEUM REFINER, page 87, two errors were made in the article by B. C. Thiel, "Controlled Water Jacket Cooling Reduces Maintenance Costs." In each the abbreviation Bhp/hr was interpreted as boiler-horsepower-hour instead of brake-horsepower-hour.

One instance was in the sixth line from the bottom of the first column and the other in the twelfth line from the bottom of the second column.

Metz Named Manager Ohio Standard's No. 1 Refinery

Appointment of Carl H. Metz, Jr., as manager of The Standard Oil Company (Ohio)'s No. 1 refinery at Cleveland was announced August 7 by G. W. Hanneken, vice president in charge of manufacturing. Metz, who has been superintendent of the refinery since April, 1937, came to company in August, 1927, as cracking coil stillman. He was named foreman a year later and assistant superintendent in 1929. A native of South Carolina, he is a graduate of The Citadel and had spent three years with American-owned refineries in Mexico before his present connection.

I. L. Peterson, assistant superintendent of the No. 1 refinery since 1937 was named superintendent of maintenance and construction. Following his graduation from the University of Illinois in 1924, he joined the company as draftsman in the engineering department at the Toledo refinery, where he was named master mechanic in 1929. Peterson served in this capacity until May, 1936, when he was transferred to the home office as assistant to Hanneken in charge of mechanical operations. He became assistant superintendent a year later.

E. S. Bale, who has been in charge of the company's technical service division since September, 1939, was named superintendent of process at No. 1 refinery. A native of Cleveland, he served as refinery engineer in the East

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for five years following his graduation from Case School of Applied Science and came to the company in January, 1939, as process control man at the Toledo refinery.

Joseph J. August, cracking coil foreman at No. 1 refinery for the past year succeeds Bale as chief of the technical service division.

Atlantic High-Octane Plant On Stream, Another Due

The Atlantic Refining Company on July 29 started operating a newly-constructed fluid catalyst cracking plant at its Point Breeze (Philadelphia) refinery. The entire structure of the cracking unit is welded and is said to be the largest welded structure in existence involving steel sections of such weight.

A similar cracking unit, shortly to be completed at the Port Arthur plant, will complete this company's program of construction for production of aviation gasoline. Minimum of difficulty in attaining normal operating efficiency at both plants is expected as a result of continuous tests conducted since last year in a pilot plant reproducing the operating conditions of the big plant.

J. S. Walton Returns To Oklahoma University

J. S. Walton, professor of chemical engineering at the University of Oklahoma, has returned to the university after a year's leave of absence, during which he acted as consultant for American contractors engaged in construction work in the Canadian Northwest and Alaska, and also served as a part-time technical consultant for Rubber Reserve Company on problems connected with catalytic production of butadiene. Prior to joining the university staff in 1941, Walton had spent 13 years in the petroleum industry, and is familiar with late developments in refining. The chemical engineering curriculum of the university will cover the new processes in proportion to their importance in the overall field of chemical enginering. He also is carrying research in catalytic reactions along with his instructional duties.

J. S. WALTON

Annual API Convention Deferred at ODT Request

William R. Boyd, Jr., president of The American Petroleum Institute has announced the institute will defer indefinitely its twenty-fifth annual meeting, scheduled to be held in Chicago November 13-16, at which an attendance of more than 3000 was anticipated.

Boyd disclosed that PIWC has asked all 108 of the industry association of national and statewide scope to give serious consideration to the ODT request for the calling off of all 1944 conventions.

Gavin and Detwiler Advanced in PAW

Appointment of M. J. Gavin and J. G. Detwiler as assistant directors of the foreign refining division of the Petroleum Administration for War was announced July 27. They will assist Director C. Stribling Snodgrass.

Gavin's duties will relate to the facilities side of the division while Detwiler's primary responsibilities will relate to the operations of foreign refineries.

Gavin joined PAW as a foreign petroleum specialist in October 1942. He started his petroleum career as an assistant chemist for Union Oil Company of California in August 1915. In 1918, he was employed by the Bureau of Mines where he remained until 1929 when he joined Foster Wheeler Corporation in Los Angeles. He served with that corporation as district manager until 1942. An honor graduate of the University of California where he majored in chemistry and chemical engineering, Gavin received his B. S. in 1915 and his E. M. in petroleum in 1923.

Detwiler joined The Texas Company as a work chemist at Port Arthur in 1911. In February 1944, he took leave from his position as supervisor of tests and specifications for The Texas Company at New York to join the PAW foreign refining division as a petroleum technologist. He served in the Army during the last war. In 1926 he was called in as a petroleum expert by British Oil Company to testify before the King's High Bench Court, London.

Gavin will be assisted in his work by L. M. Miller, chief of the facilities section, and O. G. Pratt, chief of the Russian section. C. Marvin Case, chief of the operation section, and D. S. Fraser, chief of the technical section, will assist Detwiler.

Standards of New Jersey And Louisiana Consolidate

Consolidation of Standard Oil Company of New Jersey and its wholly-owned subsidiary, Standard Oil Company of Louisiana, into one corporation will become effective at the end of this year. The announcement was made last month by M. J. Rathbone, who was president of Standard Oil Company of Louisiana until becoming president of Standard Oil Company of New Jersey last month. His statement was.

"No material change in the organization at Baton Rouge, present headquarters of the Louisiana company, is planned. The same local management will continue to handle the affairs of the company in the Louisiana territory. M. W. Boyer, executive vice president of the Louisiana company, will become a vice president of the consolidated company and will continue to be located at Baton Rouge. Sales activities will continue to be directed as at present.

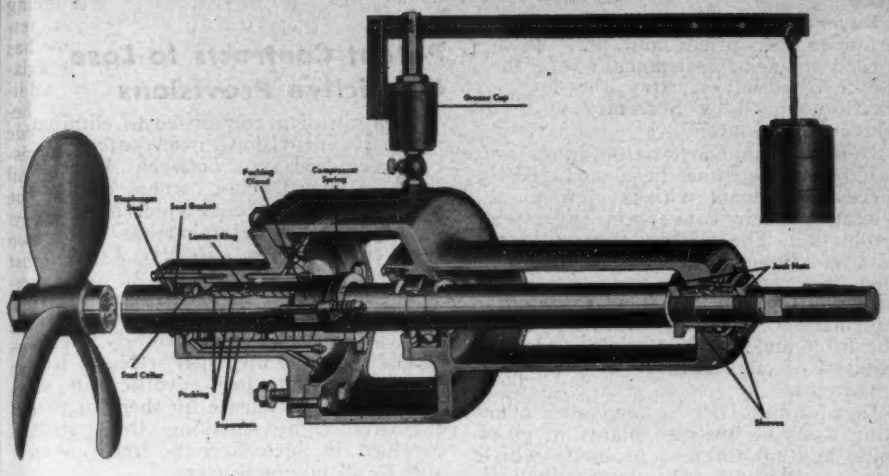
"For many years the output of the Louisiana company has been greatly in excess of the amount of products which it could sell in the territory where it has marketed directly to the public, namely, Louisiana, Tennessee and Arkansas. Increasingly larger quantities of the Baton Rouge refinery's output have been disposed of through the marketing facilities of the Standard Oil Company of New Jersey, this being particularly true during the last few years when the Louisiana company has become such a large producer of aviation and chemical products. In addition, the Louisiana company has become, through its purchases of crude oil in Louisiana, Arkansas and Mississippi, an important source of crude oil supply to the Eastern refineries of the Standard Oil Company of New Jersey. It is, therefore, natural that the two companies, in order to carry on most efficiently this large volume of interrelated business, should be consolidated. The general business policies of the two companies are identical, and consolidation of operations will result in no change as far as services to, or relationships with, the public in the territory of either company are concerned."

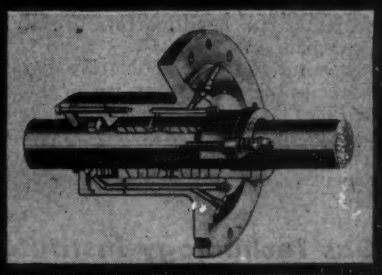
Gard Takes Over as President of C. N. G. A.

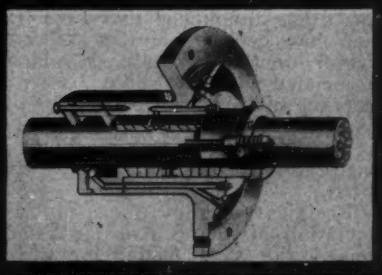
Clare D. Gard formally took over leadership of California Natural Gasoline Association to which he was elected several weeks ago, at the annual meeting of the association's directors at Los Angeles on July 11. R. W. Heath of Signal Oil & Gas Company is the retiring president.

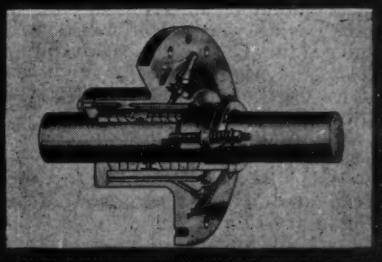
Gard, who is chief process engineer for the field department of Union Oil Company of California, advanced to that position during 23 years, having joined the company in 1921, following graduation as an electrical engineer from University of Southern California in 1917,

CLARE D. GARD









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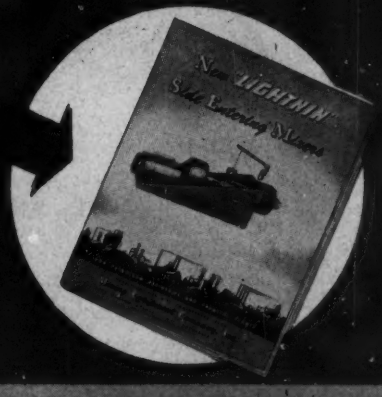

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and after service in naval aviation in the other war. His career with the company started at an experimental absorption plant, and since has been devoted to design and construction of absorption and compressor plants and to development of treating methods and plant control. Since 1941 he has headed a consolidation of engineers of the field and gas departments whose work, in addition to processing gas, involves crude-oil dehydration, waste water and secondary-recovery projects. His headquarters are at Santa Fe Springs.

Joining California Natural Gasoline Association soon after its organization in 1926, Gard has been continuously active in its work, and has served as its technical committee chairman, director, executive committeeman and vice president.

Gas Technology Institute Names Associate Director

The Institute of Gas Technology at Illinois Institute of Technology, Chicago, has announced that Leon J. Willien has been appointed associate director of the Institute. He has been associated with the Public Utility Engineering and Service Corporation of Chicago, since 1937, as a gas engineer and at present is head consultant on manufactured gas for the War Production Board.

Recipient of the American Gas Association's two top awards, Willien received the Beal medal for the most valuable technical paper read before the association's technical section at the 1927 convention. The paper was on "Developments in Water Gas Operation." Nine years later, in 1936, he received the Charles A. Monroe Award from the association for his contributions to the manufacture, mixing and transmission of gas.

He is a member of numerous other associations and honorary societies. He attended Rose Polytechnic Institute and graduated with a bachelor's degree in chemistry. Later he also received the degree of master in chemistry, and a chemical engineering degree.

LEON J. WILLIEN

RFC to Offer No Bargains in Oil, Rubber and Other Surplus Plants

Purchasers of surplus government war stocks may get some good buys as they are put on the market, but there will be no bargains in the shape of rubber, oil or other plants over which the Reconstruction Finance Corporation has jurisdiction, it was made plain last week.

Buyers of such plants, however, will be given fair prices and may be accorded financial assistance where they cannot themselves carry the load, it was announced by Secretary of Commerce Jesse Jones.

Defense Plant Corporation, Jones said, has for some time been engaged in surveys of plants with a view to accelerating their conversion to civilian production. The studies, approximately half completed, include detailed engineering reports on plants, details of cost, photographs, maps, play lay-outs; information on taxes, utilities, transportation and raw materials, and possibilities of convertibility to peace-time operations.

In addition, DPC is analyzing operating costs of different plants in given fields and of different products which are competitive, or potentially so. Where new products or processes have been developed, it is exploring methods of cutting the cost of operation and of improving both products and processes.

"Prospective purchasers of plants should not expect bargains, but will be assured of fair prices," Jones said. "Bargains would prove unfair to the purchasers' competitors and to the taxpayers of the country. While no set formula can be applied as to the sale price of the plants, the salient factors entering in such determination are present reproduction cost, the cost of adaptation to civilian production and the cost of special wartime installations having no peace-time value."

That Jones intends fully to protect the interests of the government is demonstrated by a report showing that so far he has obtained $52,000,000 for facilities which originally cost the Government $59,000,000.

New High-Cetane Fuel for Diesels Undergoing Tests

A new high-cetane diesel fuel, which gives promise of having revolutionary effects, is now undergoing extensive tests in Navy laboratories, it was disclosed last week.

The tests are being conducted to determine the value of the fuel for combat service for both present and possibly new design Navy engines. The immediate use of the new fuel lies in improving the quality of low-cetane fuels and augmenting the present supply of fuel for the many diesel ships in the U. S. fleet, it was said. Its future possibilities appear to be very promising, since it may make 100-cetane fuel practicable where 50-cetane is now the average for high quality diesel fuel.

The new high-cetane fuel is produced from a fluid obtained by synthesizing natural gas. The quantity of fuel which can be obtained from this source, however, represents only a small fraction of the total fuel production now obtained from natural petroleum but, used as a blend, it can have important effects in improving the quality of the present low-cetane petroleum fuel and increasing the over-all volume of diesel fuel available for the fleet.

Patent Contracts to Lose Restrictive Provisions

Creation of a committee to eliminate restrictive provisions from patent contracts entered into between American concerns and foreign owners of petroleum and other patents which have been seized by the government has been announced by Alien Property Custodian James E. Markham.

The committee also will have the responsibility of renegotiating with exclusive licensees under formerly enemy-owned patents for their release from payment of further royalties in exchange for the release by them of their exclusive rights, making the patents involved in such licenses freely available to all potential users.

Since our entry into the war, the APC has taken over some 45,000 patents owned by nationals of enemy and enemy-occupied countries. The main job of the committee will be the elimination from all patent agreements of restrictive arrangements which limit production or use of the patented product or the sales territory of the patent licensee.

Senator Gillette to Ask For Rubber Investigation

A new investigation of the rubber situation shortly will be undertaken by the Senate subcommittee on farm crop utilization, aimed at obtaining a further expansion of the grain alcohol program, it was disclosed August 4, by Chairman Guy Gillette of Iowa. Gillette will base his inquiry upon the whiskey "holiday" and the August-September cutback in rubber production to provide aviation gasoline stock.

"The continued operation of the alcohol butadiene plants at maximum rating and the very definite losses resulting from diversion of August production to the requirements for beverage alcohol will very probably result in the reduction of our alcohol stock pile as of September 1 to less than 40,000,000 gallons," he charged. "WPB's program has always maintained the necessity for a 100,000,000 gallon stock pile for national safety."

The precautions suggested by the senator would be in the form of new government plants for the production of 50,000,000 gallons of alcohol from grain annually.

"It is to be expected that the WPB itself is not composed of men all of whom are qualified by interest or training to evaluate the social values of this program and are over-impressed with the claims that are made that grain supplies are at the present moment short," Gillette commented.

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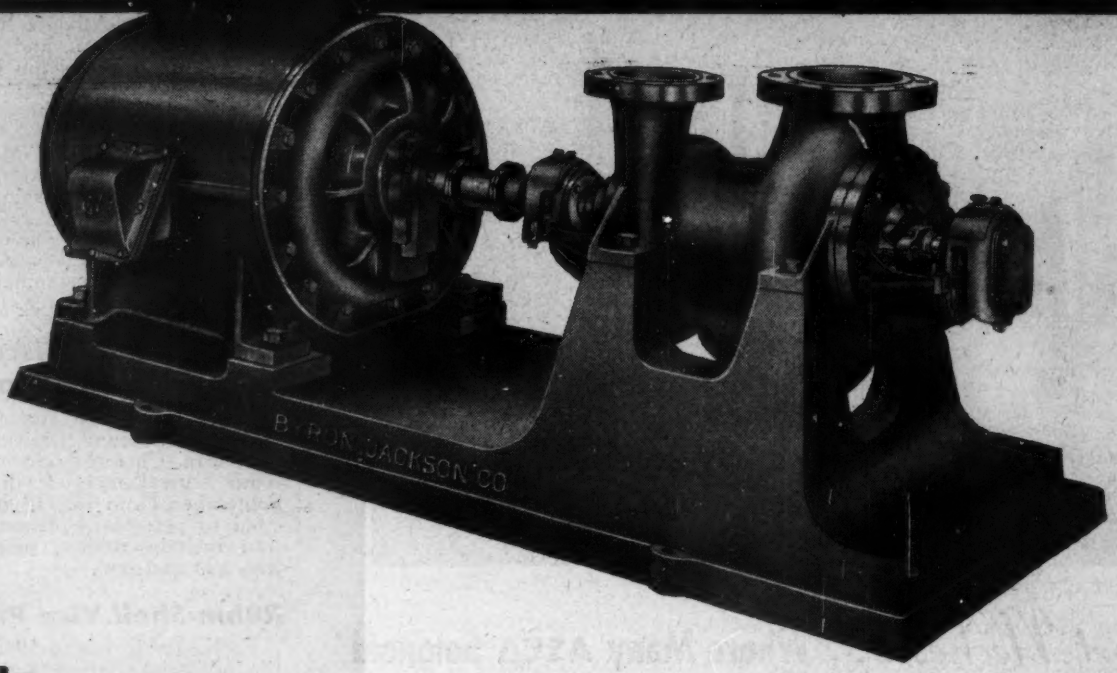

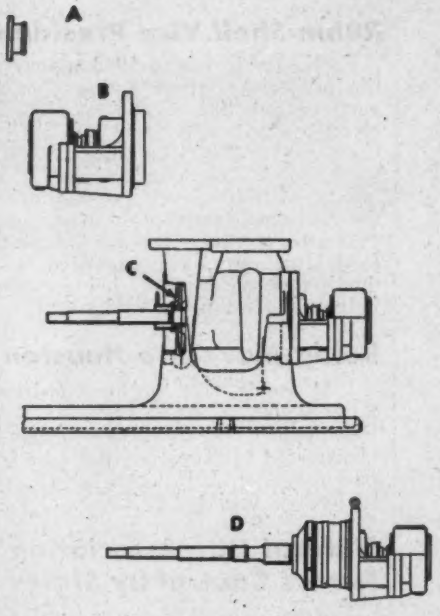

In dismantling, when the pump half of the flexible coupling (A) has been removed, the sleeve bearing housing and discharge cover (B) are withdrawn as a unit, giving access to the second stage impeller (C) which is removed with a standard impeller puller. Bolts holding the suction cover to case are then removed and the remaining portion of the rotating element (D), including the ball thrust bearing with its housing, the suction cover and the first stage impeller, are removed as a unit. Suction and discharge piping are not disturbed when dismantling the pump.

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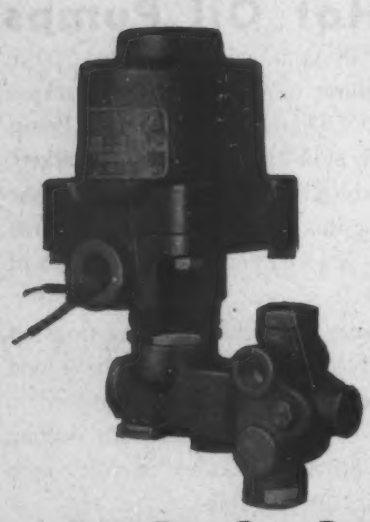

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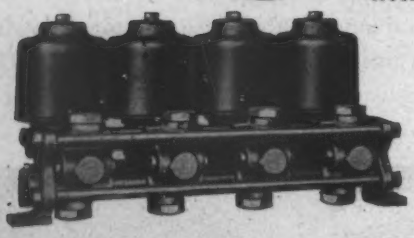

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Boyd Again Heads D-2 Committee of ASTM

T. A. Boyd, General Motors Corporation, Research Laboratories, has been reelected chairman of Committee D-2 (petroleum products and lubricants) of the American Society for Testing Materials. Also reelected were T. G. Delbridge, manager of research and development, The Atlantic Refining Company, vice chairman, and R. P. Anderson, American Petroleum Institute, secretary.

New members of the advisory committee are: C. Dantsizen, General Electric Company; O. L. Maag, Timken Roller Bearing Company; and F. D. Tuemmler, Shell Development Company. L. C. Beard, Jr., Socony-Vacuum Oil Company; L. L. Davis, Continental Oil Company; and C. A. Neusbaum, Standard Oil Development Company, complete the committee.

Chemists Will Discuss Catalysis at Annual Meet

Catalysis will be the central theme of the Petroleum Division when the American Chemical Society holds its 108th annual meeting in New York, September 11 to 15. Other subjects related to petroleum planned for discussion include rubber, petroleum, plastics, gas and fuel.

Rehm Shell Vice President

F. E. Rehm, since 1942 manager of the industrial relations and personnel department at San Francisco, has been elected a vice president of Shell Oil Company, and will continue his present work in addition to added duties as an official of the corporation. Rehm joined the company's production department in 1916 after graduation from Leland Stanford University, and advanced to production manager before being moved to industrial relations in 1938.

Reidy Moved to Houston

J. M. Reidy, who has been assistant to S. I. Hulse, vice president of Warren Petroleum Company at Tulsa, has been transferred to Houston where he is district manager. J. F. Creel has succeeded to Reidy's position at Tulsa.

Natural Gas Association Favors Control by States

Federal control of the natural gas industry was scored by the directors of the Independent Natural Gas Association at a meeting in Tulsa, Oklahoma, during which the directors went on record as favoring placing in the hands of state authorities the power to regulate the production, conservation and transportation of natural gas. The directors authorized necessary action to promote the use of natural gas and the extension of pipe lines and other facilities to available markets.

The firm of Wheat & May of Washington, D. C., was retained to represent the natural gas industry in the case of the Memphis Gas Company before the Federal Power Commission, litigation of widespread importance involving enlarging the company's transmission system, and also approved employment of counsel to be located at Washington, D. C., whose duty would be to represent the natural gas industry.

Pfaudler Pilot Plant Equipment Helps You to Determine Commercial Yield of a Laboratory Process

With the aid of Pfaudler glass-lined steel pilot plant equipment you can simulate laboratory conditions on small commercial scale. Undesirable catalytic reactions as well as the danger of metallic contamination are avoided.

This permits an exact determination of yield that can be obtained under actual operating conditions. It also provides the opportunity to make adaptations and changes in operating technique which are desirable before going into volume production.

Many companies use Pfaudler 2 and 5 gallon laboratory stills for distillation, chlorination, mixing, heating, digestion and other processes. These units are jacketed, are equipped with agitators and pulley drives. In addition, Pfaudler offers a 1 gallon glass-lined steel laboratory autoclave built for pressures up to 500 P.S.I. (Bulletin 820).

The Type "P" Series carries the process the next step into pilot plant work—units from 5 to 100 gallons are especially designed for this work. These are available with or without steam jackets, clamped on covers, anchor and impeller agitators, drives, etc.

Some have found Pfaudler pilot plant equipment ample for commercial production of small batches or for a new product while demand is light.

Larger equipment is available, of course, duplicating the basic specifications of laboratory and pilot plant vessels. Our engineers will gladly discuss your processing problem with you.

Pfaudler

Easy Maintenance Is Built Into Amsco-Nagle Pumps . . . . . .

Ready accessibility for adjustments and repairs is a dividend-paying characteristic of Amsco-Nagle pumps. This feature, in many applications, is as valued by operators as is their ability to handle abrasive and corrosive liquids for maximum periods before requiring attention.

In designing Amsco-Nagle pumps, consideration was given the importance of accessibility for keeping down maintenance costs and reducing to a minimum each "time out" period.

Indicated in the illustration below (P-40-N) are three points of accessibility which add up to savings in time on adjustment and maintenance. This is an Amsco-Nagle 10″ Type "T," frame 29, vertical discharge pump. The type "T" is a single stage, side action horizontal pump of high mechanical and hydraulic efficiency, with wide impeller clearance for free passage of debris-laden liquids, slime, sludge and slurry.

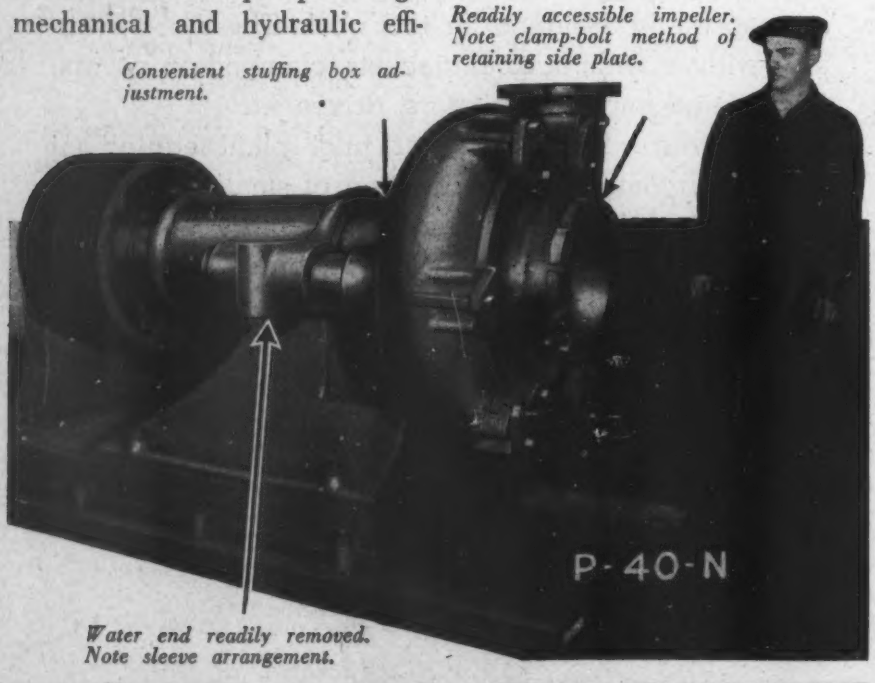
The stuffing box is opened by simply removing the cover cap when adjustment or repacking is needed. Slippage seal adjustment is easily made. The method of mounting the water end on the base, using tube supports, maintains accurate alignment and permits removal of the water end by loosening two bolts. The plate is easily removed by loosening clamp bolts. The impeller screws off.

Amsco-Nagle pumps are made in two horizontal and four vertical types, and in sizes from ¾″ to 16″, for heads up to 200′ and capacities up to 10,000 g.p.m.

Ask for Bulletin No. 940.

Readily accessible impeller. Note clamp-bolt method of retaining side plate.

Convenient stuffing box adjustment.



Water end readily removed. Note sleeve arrangement.

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OFFICES IN PRINCIPAL CITIES

AMERICAN Brake Shoe COMPANY

PAW to Pass on All Oil Projects Up to $100,000

The War Production Board delegated authority to PAW in the handling of oil-industry construction projects, empowering it to pass on projects costing up to $100,000, as against the $25,000-maximum to which it had previously been limited.

Prior to the new arrangement construction project applications over $25,000 were approved by PAW and reviewed and given final approval by WPB. Now, all projects up to $100,000 will be handled by PAW, it being estimated that 95 percent of construction will come within the jurisdiction of the agency.

It was pointed out that the new system will expedite movement of material and equipment to new facilities.

Postwar Fate of High-Octane Plants

Among reconversion problems which will confront the oil industry after the war is the problem of what to do with the 100-octane gasoline plants which are today producing in excess of 400,000 barrels of aviation fuel a day.

John Day, executive manager of the Western Petroleum Refiners Association, believes that some plants will be scrapped while others will have to be re-vamped so that they can produce an economic motor fuel. In any event, the industry will have to use its ingenuity in order to save the millions spent for 100-octane gasoline plant construction.

While postwar military requirements for aviation gasoline cannot be estimated—these being governed by international factors to be settled at the peace table—civilian needs will run between 35,000 and 50,000 barrels per day, in Day's opinion.

Aviation gasoline will be used by commercial airlines, private plane owners and training centers in the proportion of 10,000 barrels a day each for airlines and private plane owners and 20,000 for training requirements.

This still leaves 350,000 barrels a day of aviation gasoline still to be absorbed. The automobile of the future will not burn 91-100 octane fuel. It would be too expensive in any case, since regular motor fuel costs an average of six cents a gallon, not including taxes, and 91-100 octane costs about 13½ cents a gallon.

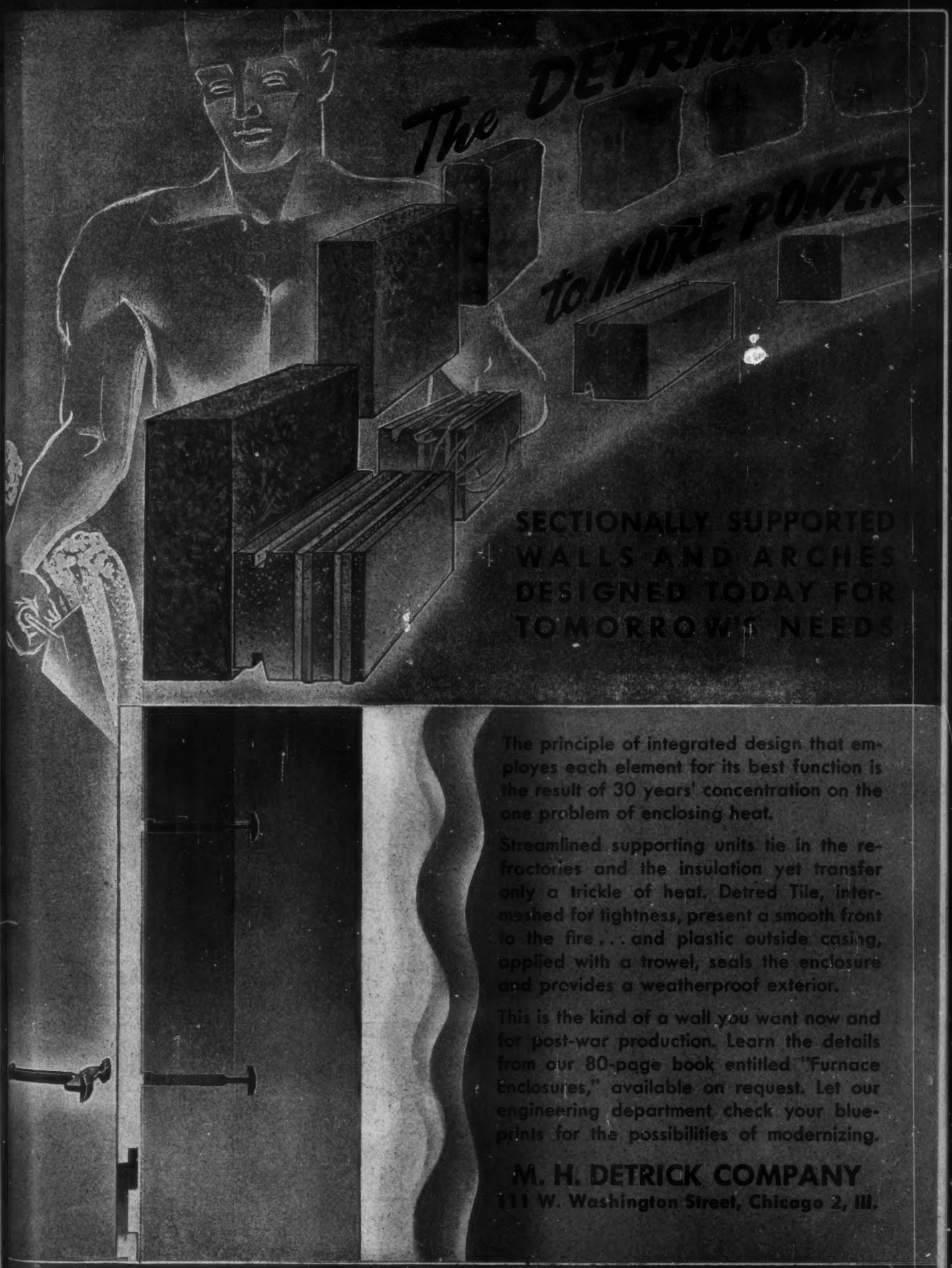
Day predicts continued foreign exports of aviation gasoline immediately after the war, but not indefinitely. Reconversion or scrapping seems to be the only solution.

Surplus of Metal Drums Being Sold by Government

A large quantity of 55-gallon metal drums, probably in the neighborhood of 100,000, are being offered for sale by the procurement division of the Treasury Department. The drums have been declared surplus by various military units, it was said.

The division disclosed that more than 270,000 drums have been declared surplus during the past 60 days more than half of which have been sold to state organizations, farmers, oil and chemical companies.

Currently, the Treasury is offering the balance to oil companies, wholesalers and other in-the-trade distributors. Information regarding the drums can be secured by contacting any of



The principle of integrated design that employes each element for its best function is the result of 30 years' concentration on the one problem of enclosing heat.

Streamlined supporting units tie in the refractories and the insulation yet transfer only a trickle of heat. Detred Tile, intermeshed for tightness, present a smooth front to the fire . . . and plastic outside casing, applied with a trowel, seals the enclosure and provides a weatherproof exterior.

This is the kind of a wall you want now and for post-war production. Learn the details from our 80-page book entitled "Furnace Enclosures," available on request. Let our engineering department check your blueprints for the possibilities of modernizing.

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145 Sussex Ave., Newark - 1, N. J.

A DIVISION OF ELLIOTT COMPANY

the Treasury's regional offices in Boston, New York, Cincinnati, Chicago, Atlanta, Fort Worth, Kansas City, Denver, San Francisco or Seattle.

The procurement division also is preparing to sell 6925 trucks of various types and sizes which it will sell to oil companies, coal companies and dealers.

Shell Building Chemical Plant at Houston

Shell Chemical Division of Shell Union Oil Corporation plans construction of an allyl chloride and allyl alcohol plant at Houston, construction to begin at once. The new-type plant is the result of many years of research and development work on the part of Shell Development Company. While allyl chloride and allyl alcohol will have many interesting uses in the synthetic chemical industry, it is expected that immediate application of the output of the new plant will be in the field of plastics for aircraft and war material construction.

Expanding Plant

Humble Oil & Refining Company is practically doubling capacity of its gasoline plant at Tomball (Harris County, Texas) by installation of four additional 600-horsepower compressing units and a dehydrating unit. Work is expected to be completed within 90 days.

The plant will process 8 million feet of low-pressure gas currently being wasted, and withdrawal of high-pressure gas will be curtailed as a further conservation measure.

Shell Building Cycling Plant in Texas Area

Shell Oil Company is constructing a cycling plant near Sheridan, Colorado County, Texas, to have initially a daily capacity of one hundred million cubic feet of gas, and it is expected to produce approximately 6000 barrels isobutane, normal butane, isopentane, normal pentane, natural gasoline and condensate daily. Sixty-four hundred horsepower will be used in the engine room for recompression purposes.

Petroleum Engineering, Inc., has the construction contract, and it is expected the plant will be completed in the early spring of 1945.

Restrictions Relaxed on Materials for Refining

Extension to refining and transportation operations of the relaxation of restrictions on the use of materials was provided by PAW July 27 by amendment of PAO 15.

Automatic authorization is now granted for use of materials for the construction, installation or extension of any operation directly incident to refining or transportation to a maximum material cost for any one complete operation not exceeding $10,000, as against the former maximum of $5,000.

Provisions of the order permitting the use of up to $500 worth of material for any purpose, even if it originally had been obtained for maintenance and repair purposes, were revoked in favor of provisions of the recently-amended WPB order P-98-B under which an operator may automatically obtain an AA-1 priority rating for material costing up to $500, which may be used for any purpose.

REPEAT ORDERS

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COMPANY B	1	8	16	16	3		5 ORDERS
COMPANY C	1	1	1	1	1		5 ORDERS
COMPANY D	1	1	1	6	1		5 ORDERS
COMPANY E	1	1	1	16			4 ORDERS
COMPANY F	1	1	2	1			4 ORDERS
COMPANY G	1	2	1				3 ORDERS

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DIGEST OF UNITED STATES PATENTS

ON ISOMERIZATION OF HYDROCARBONS III

the Hydrocarbon Synthesis

Compiled by HEINZ HEINEMANN

U.S.P. 2,323,830. Catalytic Conversion Process. F. M. McMillan to Shell Development Company.

In an isomerization process wherein butane is passed under isomerization conditions through an elongated reaction zone containing a bed of catalytic material consisting of adsorptive alumina impregnated with anhydrous aluminum chloride followed by an adjoining bed of adsorptive alumina, the method of prolonging the useful life of said catalytic material is claimed which comprises the steps of intermittently withdrawing from the reaction zone a part of the catalytic material farthest removed from the bed of adsorptive alumina, said catalytic material being substantially spent, treating said withdrawn part outside of the reaction zone to recover and regenerate the adsorptive alumina contained therein, passing anhydrous aluminum chloride vapors through the remaining partially spent catalytic material and the adsorptive alumina in situ to simultaneously increase the catalytic activity of said partially spent material and render the adsorptive alumina catalytically active by impregnation and returning the regenerated adsorptive alumina to the outlet end of the reaction zone.

U.S.P. 2,324,746. Catalytic Isomerization of Paraffinic Hydrocarbons. W. W. Weinrich and J. M. Yost to Gulf Research and Development Company.

For the isomerization of normal paraffinic hydrocarbons by means of an aluminum halide catalyst and a hydrogen halide promoter, a procedure is suggested which employs a series of three catalyst beds, consisting of supported aluminum chloride. The first and third bed are small and have about ⅓ to ¼ the size of the middle, large bed. Paraffin vapors are passed over the three beds, the first and second being maintained at isomerization temperature, the third at aluminum halide condensation temperature. After the aluminum halide concentration of the first bed has decreased markedly and the concentration of the third bed has increased but not beyond 35 percent $AlCl_3$, the flow is reversed, again keeping the first two beds at isomerization and the last at aluminum halide condensation temperature.

U.S.P. 2,324,762. Isomerization Process. V. B. Calhoun and K. C. Laughlin to Standard Oil Development Company.

Isomerization of straight-chain paraffins having at least four C atoms per mol can be effected in the presence of a catalyst composed of metallic nickel, cobalt or iron deposited or impregnated upon a hydro-halide-treated clay such as Super Filtrol, bentonite, montmorillonite, Marsil or similar clays. The activity of the catalyst can be further enhanced by the addition of substantial amounts of free hydrogen to the reaction. Preferably the metallic constituent is prepared in situ, by reducing a salt-impregnated clay with hydrogen. The catalyst is less effected by sulfur than other isomerization catalysts. The reaction is carried out at 550-700° F. for periods of 0.5—4 hours contact time. From 100 to 300 pounds per square inch of free hydrogen pressure are maintained in the reaction chamber.

U.S.P. 2,325,122. Treatment of Butane. V. N. Ipatieff to Universal Oil Products Company.

Various proportioned mixtures of boron trifluoride and hydrogen fluoride have a catalytic effect in isomerizing n-butane to produce i-butane where this catalytic property is not exhibited by either of the compounds separately. As a rule an excess of BF_3 is used, such as 17 parts by weight of BF_3 to 13 parts of HF. The reaction takes place at atmospheric temperature to 300° C. and atmospheric or slightly superatmospheric pressure.

U.S.P. 2,326,627. Treatment of Hydrocarbon Oils. G. Egloff and V. Komarewsky to Universal Oil Products Company.

A process for conversion of hydrocarbon oil into more valuable products is claimed, which comprises mixing said oil with $AlCl_3$ to form a slurry, heating said slurry to a conversion temperature, introducing the heated slurry to one end of a reaction zone and therein effecting conversion of said oil in the absence of any external application of heat, withdrawing conversion products from the opposite end of said zone at a rate that no substantial accumulation of a liquid takes place therein, simultaneously in a second heating step heating a mixture of hydrogen and hydrogen chloride to a temperature above said conversion temperature and supplying the thus heated mixture to said reaction zone to supply heat and promote the desired reaction.

U.S.P. 2,326,703. Isoforming. E. W. Thiele and G. E. Schmitkons to Standard Oil Company (Indiana).

To improve its anti-knock rating, thermally cracked naphtha is contacted with a moving bed of a catalyst comprising silica and a metal oxide at a pressure of from about atmospheric to 50 pounds per square inch and at a temperature of about 875-1150° F. The catalyst is retained in the contacting zone for 3 to 60 hours and a space velocity of 4 to 60 volumes of liquid cracked naphtha feed per volume of catalyst space per hour is maintained.

U.S.P. 2,327,188. Treatment of Paraffins. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

Normal butane is contacted with a composite of substantially anhydrous chlorides of aluminum and zinc and a porous adsorbent in the presence of a hydrogen halide at 125° C. and higher and 10 to 200 atmospheres pressure. A conversion of 30 to 60 percent is obtained per pass.

U.S.P. 2,327,593. Catalytic Isomerization of Saturated Hydrocarbons. M. deSimo and F. M. McMillan to Shell Development Company.

In a process for the isomerization of an isomerizable saturated hydrocarbon with an aluminum halide catalyst the improvement is claimed which comprises contacting the hydrocarbon under isomerization conditions with a catalyst consisting essentially of an effective amount of anhydrous aluminum chloride and an adsorptive alumina which has been prepared by partially dehydrating a crystalline alumina alpha trihydrate formed by precipitation from a solution of sodium aluminate.

U.S.P. 2,327,670. Isomerizing Hydrocarbons. W. E. Ross and J. Anderson to Shell Development Company.

Normal and branched-chain saturated hydrocarbons can be isomerized to branched- and more highly branched-chain saturated hydrocarbons by contact with a fluid melt comprising aluminum chloride, sulfur dioxide and zinc chloride in a molar ratio of about 2:1:½ resp. at temperatures not exceeding 100° C. A hydrogen halide promoter is preferably present in amounts of 0.3 to 10 percent of the hydrocarbon charge. Up to 58 mol percent of normal butane can be converted to iso butane.

U.S.P. 2,328,753. Isomerization of Olefins. C. L. Thomas to Universal Oil Products Company.

Olefins of at least four C atoms per mol are isomerized at 400 to 1050° F. with an isomerizing catalyst substantially free of alkali metal ions comprising a calcined mixture of precipitated hydrated silica and a hydrated oxide selected from the group consisting of precipitated alumina and precipitated zirconia.

U.S.P. 2,330,071. Treatment of Hydrocarbons. W. J. Mattox to Universal Oil Products Company.

Straight-chain or mildly branched olefinic hydrocarbons are isomerized by contacting them at 300 to 400° C. and atmospheric to 10 atm. pressure at a space velocity of 0.1-10 liquid volumes/volume/hour with formed particles of alunnite or a mixture of alumnite and a carrier such as clay, diatomaceous earth, fuller's earth, silica, alumina, magnesia, etc.

U.S.P. 2,330,079. Process for Isomerizing Paraffinic Hydrocarbons. J. J. Owen to Standard Oil Development Company.

In process for isomerization of lower paraffinic hydrocarbons, using an aluminum chloride catalyst and a hydrogen halide promoter, the amounts of promoter necessary for optimum operating

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BUILDING separate vaults or housings to isolate electric equipment from explosive and corrosive atmospheres is costly. It wastes engineering and installation time. It complicates maintenance. So do cumbersome remote-drive arrangements.

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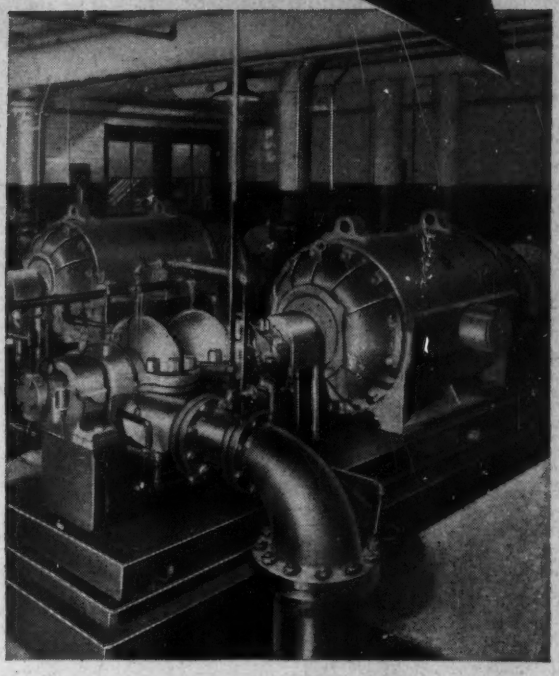
Whether it's high-octane gasoline, toluene, natural gas, acid fumes, or outdoor service, there's a way to meet your conditions with a combination of G-E motors and control. For General Electric builds the most complete line of motors and control devices for use in Class I as well as Class II locations.

And—assistance in selecting the motors and control which best combine security and economy on your jobs is right within reach of your telephone. G-E engineers specializing in refinery applications will be glad to have you call on them via the G-E office near you.

BUY ALL THE BONDS YOU CAN—*AND KEEP ALL YOU BUY*



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conditions can be reduced materially by adding free water to the reaction zone in amounts to keep from 0.1-2.0 percent by weight (based on the total hydrocarbons present) of water in the reaction zone at all times. Since some water is retained by the catalyst and larger amounts of water spoil the catalyst, introduction of water must be carefully regulated.

U.S.P. 2,330,115. Catalytic Isomerization of 1-Olefins to 2-Olefins. H. E. Drennan to Phillips Petroleum Company.

A novel catalyst for the isomerization of butene-1 is described which is active at such conditions of temperature and flow rate that equilibrium concentrations of butene-2 are obtained with negligible losses of olefins and diolefins through polymer formation. The catalyst consists of bauxite of suitable particle size treated with concentrated or diluted non-volatile strong mineral acid (H_2SO_4, H_3PO_4) in such proportions that 10 to 50 percent by weight of acid is added to the bauxite. The isomerization reaction is carried out at 150 to 600° F.

U.S.P. 2,330,754. Isomerization of Hydrocarbons. W. E. Skelton, E. E. Sensel and A. R. Goldsby to The Texas Company.

In the process of isomerizing gaseous hydrocarbons by passing them through a catalytic mass comprising metal halides, the catalyst is slowly poisoned by the deposit of impurities, such as polymers on the catalyst. According to the invention the process is operated at 210-220° F. and 150-215 pounds per square inch and the pressure is intermittently raised to 275 pounds per square inch to liquefy hydrocarbons and wash the catalyst with liquid hydrocarbons to remove the impurities deposited and prolong the catalyst life.

U.S.P. 2,330,787. Isomerization of Normal Paraffins. S. F. Birch and J. H. Beynon to Anglo-Iranian Oil Company.

An anhydrous ferric halide such as ferric chloride is added as a catalytic promoter for the isomerization of n-butane or n-pentane, when an aluminum halide such as aluminum chloride is used as a catalyst or when the aluminum halide is used together with hydrogen chloride as promoter. The proportion of ferric halide employed varies from 1.75 to 20.0 percent by weight of the aluminum halide. The reaction temperature is 50 to 200° C.

U.S.P. 2,332,577. Treatment of Hydrocarbons. W. S. Kassel to Universal Oil Products Company.

A combination isomerization and alkylation process is described in which the isomerization step is carried out in the presence of hydrogen and hydrogen halide, using a metal halide catalyst.

U.S.P. 2,331,429. Isomerization of Hydrocarbons. E. E. Sensel and A. R. Goldsby to The Texas Company.

Gasoline hydrocarbons are treated with fresh metallic halide, such as $AlCl_3$, under isomerizing conditions at relatively low temperatures, during which treatment the catalyst, at least in part, is converted to a metallic halide-hydrocarbon complex. The complex is subsequently subjected to contact with feed hydrocarbons at somewhat higher temperatures, so that it is effective in isomerizing normal paraffinic constituents of the feed. The treatment with fresh

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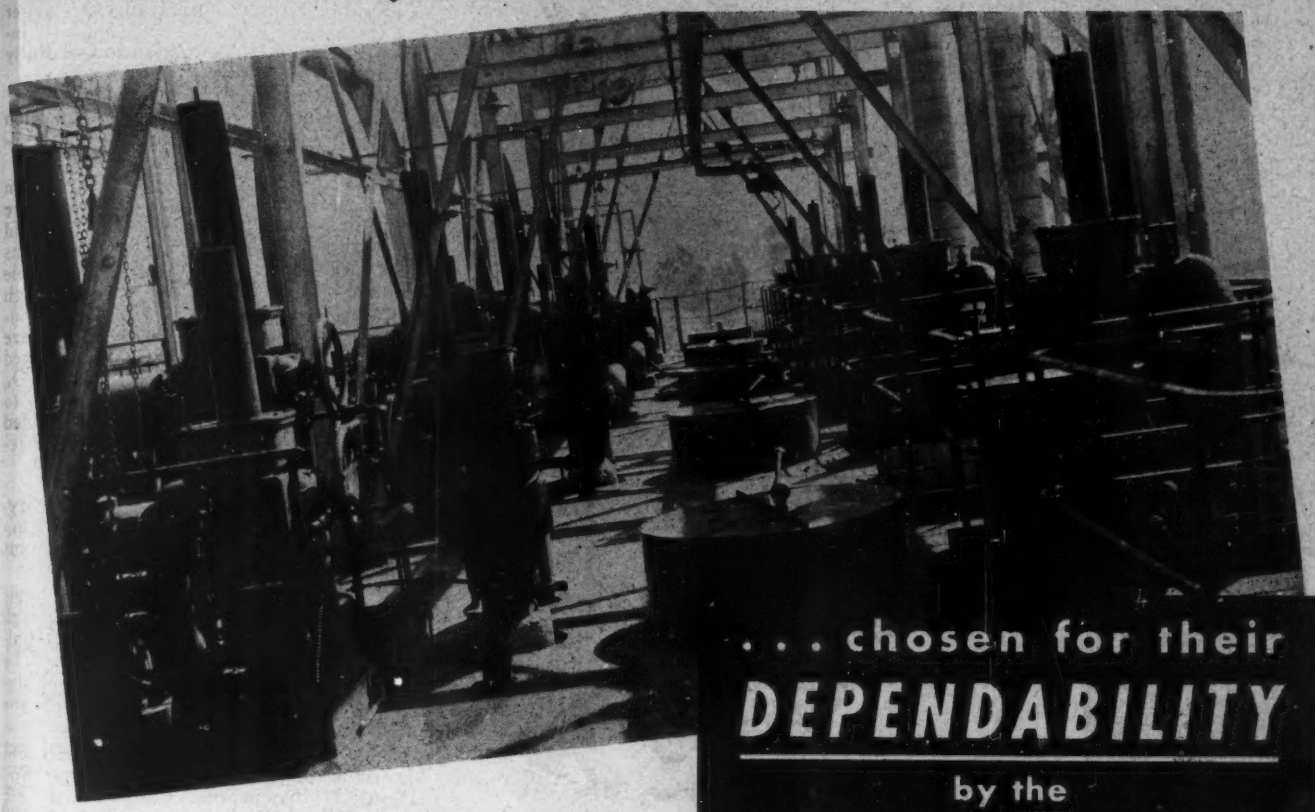

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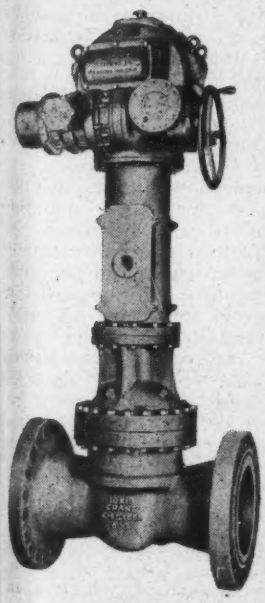
The photograph above illustrates a large group of Type O.S. LimiTorque Controls installed in the hydroformer plant of the Oleum Refinery of Union Oil Company of California. It is typical of the great many installations of these valve operators, where the dependability of the controls to function for long periods without maintenance or repairs was a most important factor in their selection. The design of the LimiTorque Controls permits high speed operation, thus assuring maximum production.



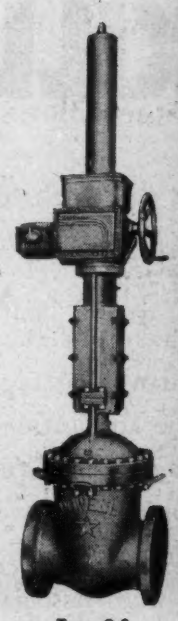
TYPE S.C.

TYPE O.S.

This type unit is designed for mounting on top of the valve yoke flange. It consists essentially of a motor driven combination helical and worm gear reducing mechanism with limit and torque switches in a rugged, weatherproof and dust-tight housing. Can be used on valves up to 96" diameter.

TYPE S.C.

The crank type mechanism employed enables it to open and close valves much faster than can a conventional type operator. Further, it is so trouble-free that it can be operated for a year or more without the need of shutting down the line for repairs or adjustments to the control.



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metallic halide is carried out with a hydrocarbon fraction boiling below 220° F., and at a temperature of 175 to 270° F. The complex is used to isomerize hydrocarbons boiling above 220° at considerably higher temperatures.

U.S.P. 2,332,275. Isomerization of Paraffins. E. E. Stahly to Standard Oil Development Company.

Lower-boiling normal paraffinic hydrocarbons are converted to iso paraffinic hydrocarbons in the absence of essential amounts of olefins by the action of a catalyst consisting of a double salt complex of a Friedel-Crafts type catalyst and an alkali metal halide in proportions between about 1.1:1 and 2.5:1. The double salt complex is formed below 400° F. and the molten catalyst is preferably poured over a heated granular carrier, with a NaCl : $AlCl_3$ catalyst normal butane is isomerized at 150-225° F., normal pentane at 30-150° F.

U.S.P. 2,333,903. Treatment of Hydrocarbons. C. L. Thomas and H. S. Bloch to Universal Oil Products Company.

Isomeric methylcyclopentenes are produced from cyclohexene by contacting the latter at 200-450° C. and 1-10 atmospheres pressure with a calcined mixture of the hydro-gels of silica and alumina, which may be composited with zirconia, using a liquid space velocity of about 0.5-20. The catalyst activity is relatively constant for a wide range of proportions of the components.

U.S.P. 2,334,553. Apparatus and Process for Catalytic Reactions of Low-Boiling Hydrocarbons. C. T. Harding to Standard Oil Development Company.

A process for isomerizing liquefied n-butane with a catalyst comprising $AlCl_3$ at temperatures in the range from about 150 to 300° F. while said n-butane is maintained under sufficient pressure to remain in the liquid phase, which comprises flowing upwardly a stream of the liquefied n-butane containing the catalyst in suspension into a reaction zone at a controlled velocity to maintain a concentration of catalyst within said zone and to deplete the concentration of the catalyst in liquefied hydrocarbons flowing from and upwardly beyond said reaction zone, accumulating a liquid body of n-butane and i-butane above said reaction zone, cooling said liquid body, withdrawing a portion of liquefied butanes from said liquid body for recovery of i-butane, and recycling another portion of said liquid body to said reaction zone for further isomerization.

U.S.P. 2,334,998. Isomerization of Alpha Olefins. A. A. Draeger and J. J. Savelli to Standard Oil Development Company.

A process is described which comprises contacting in an isomerization unit a refinery C_4 cut containing substantial amounts of butene-1 but substantially free of isobutylene with a catalyst prepared by treating 70 percent H_2SO_4 at between 140 and 158° F. with said refinery C_4 cut until the acid is substantially saturated with n-butylenes, at a temperature of about 158° F. for 60 minutes with vigorous agitation under sufficient pressure to maintain liquid phase. Substantial quantities of butene-1 are converted to butene-2. The reaction mixture is settled to form an acid phase and a hydrocarbon phase. The hydrocarbon phase is withdrawn and distilled into a fraction containing substantially all of the unconverted butene-1 and a

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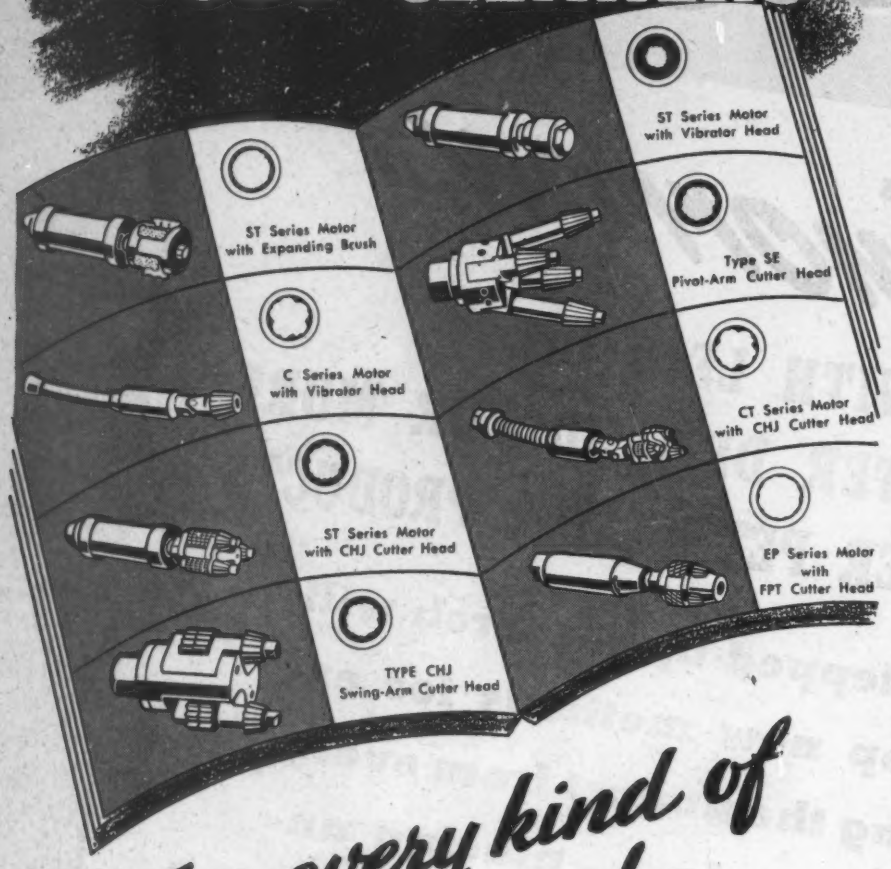
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fraction containing substantially all of the butene-2 formed. The feed stock may be prepared from a C_4 cut from which the iso-butylene has been substantially completely removed by a selective absorption and polymerization process.

U.S.P. 2,335,406. Treatment of Hydrocarbons. A. R. Goldsby and E. E. Sensel to The Texas Company.

Normal pentane is isomerized in the presence of two to four parts of iso butane per part of pentane, by contacting it with aluminum chloride and hydrogen chloride at 130 to 300° F. for 1 to 15 minutes. The iso butane substantially reduces cracking and retards catalyst deterioration.

U.S.P. 2,336,600. Production of Branched-Chain Alkenes. E. W. M. Fawcett to Anglo-Iranian Oil Company, Ltd.

Isomerization catalysts are employed which consist of an acid phosphate of a metal of group I, II, III, IV, VI, VII or VIII of the periodic system, which has a phosporus: metal ratio greater than that of the normal phosphate of the metal. The catalyst may be prepared for use in a solid, dry, hard and porous state and consist of a single acid phosphate or a mixture of acid phosphates of more than one metal. The catalysts inhibit polymerization, particularly when the alkene feed stock is diluted with nitrogen, hydrogen, water vapor, methane, butane or other paraffins. Isomerization is carried out at 250° to 400° C. and at superatmospheric pressure.

U.S.P. 2,336,862 and 2,336,863. Isomerization of Paraffins. A. V. Grosse and H. Pines to Universal Oil Products Company.

A process for isomerizing a normally liquid paraffinic hydrocarbon boiling in the gasoline range is described which comprises subjecting said paraffin under isomerizing conditions of temperature, pressure and time to the action of an isomerizing catalyst of the Friedel-Crafts type in the presence of added hydrogen halide, said temperature being in the approximate range of 50 to 250° C., and correlating the amount of hydrogen halide and said isomerizing conditions to effect, as the principal reaction in the process, conversion of a substantial portion of said paraffin into an isomer or isomers thereof, having the same molecular weight as said paraffin.

U.S.P. 2,337,015. Catalytic Conversion. C. C. Crawford and W. E. Ross to Shell Development Company.

Catalysts for liquid-phase isomerization are obtained by combining an aluminum halide such as $AlCl_3$ with a halide salt of a cyclic nitrogen base containing the nitrogen atom within the ring, such as a halide salt of pyridine, pyrollidine, quinoline, alkyl derivatives thereof, etc. A particularly efficient catalyst consists of an eutectic mixture of $AlCl_3$ and pyridine hydrochloride (66 percent by weight $AlCl_3$, 34 percent pyridine hydrochloride) which melts at 40° C. These mixtures can undergo subcooling to an unusual degree and the eutectic mixture can be used in liquid state at as low as 0° C. The reaction temperature should not be in excess of 65° C.

U.S.P. 2,337,418. Destructive Isomerization. R. F. Ruthruff.

Heavy naphtha is converted into iso butane and iso paraffinic light naphtha by contacting it at 100-800° F. with a

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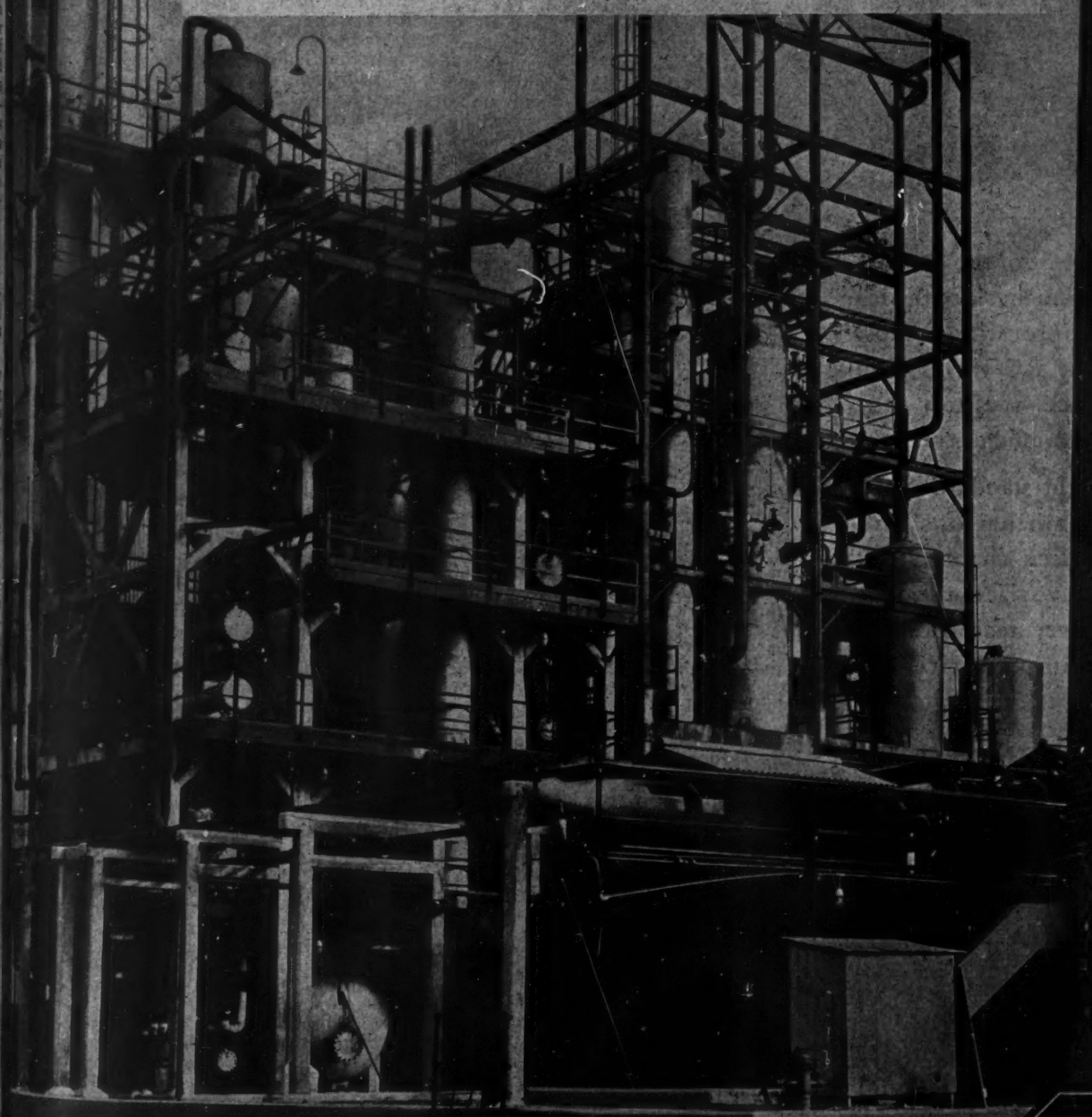

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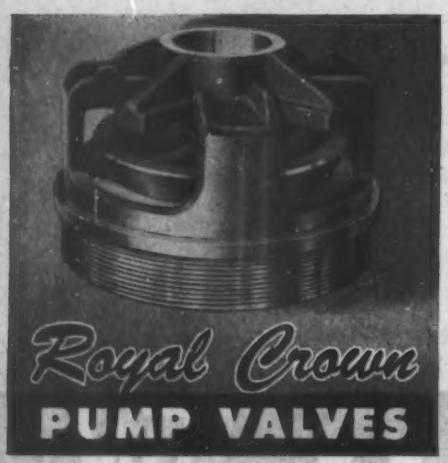

mixture consisting of an aluminum halide in intimate association with a metal selected from the group consisting of aluminum, magnesium, and zinc, for a sufficient period to convert a substantial portion of the heavy naphtha. The metal may be activated by being in intimate association with a minor quantity of an element having an electrode potential below that of the metal, such as mercury, cobalt, cadmium, nickel, iron, and the like.

U.S.P. 2,337,419. Catalytic Conversion of Hydrocarbons. E. E. Sensel to The Texas Company.

In accordance with the invention a metallic halide catalyst such as aluminum chloride in lump or other fragmentary form is disposed in a plurality of shallow beds supported one above the other within a reaction tower. Each bed is spaced substantially apart and traps are provided in the spaces between succeeding beds, the traps being adapted to collect and continuously discharge liquid drip from each catalyst bed. The feed hydrocarbon after being heated to reaction temperature is passed in a continuous stream of vapor through the reaction tower, flowing through the succeeding beds in series. The stream of hydrocarbons, including isomerized hydrocarbons, is withdrawn from the reaction tower after passage through the final catalyst bed in the series.

U.S.P. 2,337,601. Treatment of Natural Gasoline. H. L. Hays to Phillips Petroleum Company.

A combination process involving the isomerization of a low-boiling natural-gas fraction is described.

U.S.P. 2,338,471. Isomerization of Hydrocarbons. A. J. van Peski to Shell Development Company.

A method for increasing the active life of an $AlCl_3$ isomerization catalyst and decreasing the rate of dilution of recycled HCl promoter with gaseous degradation products is described, which comprises the combination of steps of subjecting the hydrocarbon fraction to be isomerized to a catalytic hydrogenation treatment to produce a substantially olefin-free hydrocarbon fraction, subjecting the thus treated hydrocarbon fraction to a topping treatment to remove traces of materials boiling below about —10° C. and treating the substantially olefin-free hydrocarbon fraction with a substantially hydrocarbon-insoluble alkali.

U.S.P. 2,338,568. Isomerization of Paraffinic Hydrocarbons. J. H. Bartlett to Standard Oil Development Company.

It is known that Friedel-Crafts type catalysts for isomerization reactions require activators such as hydrogen halides. It has been found that the low-molecular-weight aliphatic alcohols and the ethers prepared therefrom are excellent catalyst activators which are non-corrosive. The best activators are the alcohols with less than four C atoms per mol and the ethers prepared therefrom. The method of introduction of the activators is unimportant as long as they are present when the n-paraffin contacts the catalyst. The amount of activator used corresponds to 0.5-10.0 percent of the hydrocarbon charged.

U.S.P. 2,339,849. Treatment of Hydro-Carbons. A. R. Goldsby and E. E. Sensel to The Texas Company.

When isomerizing higher-boiling normally liquid hydrocarbons in the presence of anhydrous metal halides and hydrogen halide, considerable difficulty is encountered due to cracking and other side reactions. These side reactions and accompanying deterioration of the catalyst are according to the invention inhibited or minimized by carrying out the isomerization operation in the presence of an added iso paraffin of the class of iso butane and iso pentane in amounts (by weight) substantially in excess of the weight of the naphtha feed. The treatment is carried out below 300° F.

U.S.P. 2,342,073. Isomerizing Hydrocarbons. H. A. Cheney to Shell Development Company.

Fluid melts consisting of ternary mixtures composed of a molecular excess of a halide of aluminum, a halide of sodium and a halide of potassium are desirable catalysts for the isomerization of hydrocarbons. The isomerizable hydrocarbon, for instance n-butane is contacted at a temperature not exceeding 110° C. with a fluid melt of $AlCl_3$, NaCl and KCl in the weight ratio of about 8:1:1. The isomerization reaction is preferably effected in the presence of a hydrogen halide promoter. Gases such as hydrogen, nitrogen, methane, carbon dioxide, etc., may, is desired, be present in the reaction zone.

U.S.P. 2,342,248. Catalytic Isomerization of Olefins. R. E. Burck to Standard Oil Company of California.

Olefins are isomerized by contacting with a mass consisting of a co-precipitated gel mixture of 20:80 mol percent of chromium and aluminum oxides, at a temperature below that for aromatizing and in a range of about 750-800° F. substantially without hydrogen split-off, while maintaining the pressure about atmospheric.

U.S.P. 2,342,922. Conversion of Hydrocarbons. U.S.P. 2,342,923 Isomerization of Hydrocarbons. J. D. Danforth to Universal Oil Products Company.

Hydrocarbon mixtures consisting of higher-boiling and lower-boiling constituents are fractionated into a lower-boiling and a higher-boiling fraction and the lower-boiling fraction (below 100° F.) is passed through a bed of granular metal halide to dissolve a part thereof. The solution of metal halide is combined with the heavier hydrocarbon fractions and a hydrogen halide and the combined materials are introduced into a reactor containing granular, relatively inert packing material. The products from the reactor are fractionated to produce fixed gases, comprising essentially a hydrogen halide, an isomerized product of desired boiling range and heavier fractions. The hydrogen halide is recycled.

U.S.P. 2,343,406. Isomerization of Paraffins. C. G. Dryer to Universal Oil Products Company.

Hydrocarbons are contacted with an isomerization catalyst under conditions of temperature and pressure so controlled as to maintain the hydrocarbons in a substantially liquid phase. The hydrocarbons and the catalyst form a mixture containing sufficient catalyst to promote isomerization. This mixture together with the desired amount of hydrogen halide promoter is introduced to a packed reaction zone which is maintained under processing conditions so regulated that the reaction mixture is substantially in vapor phase and the dominating reaction is the formation of isomeric hydrocarbons. The resulting liquid is fractionated at a pressure higher

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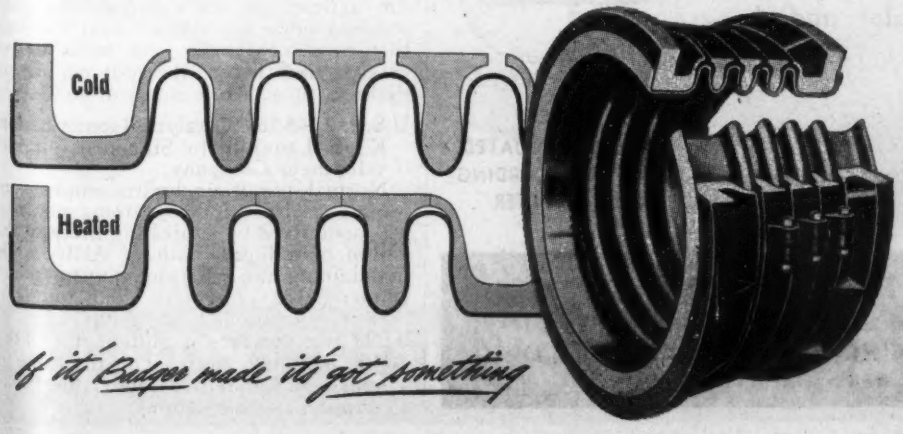

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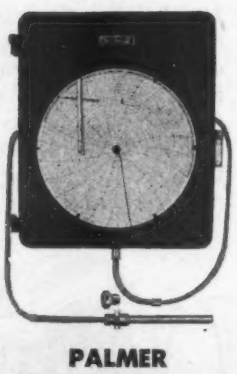

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than the reaction zone pressure and the hydrogen halide and unconverted material are separated from the reaction mixture and recycled back to the reaction zone.

U.S.P. 2,344,466 and 2,344,467. Catalytic Isomerization. K. C. Laughlin and E. D. Reeves to Standard Oil Development Company.

An improved process for isomerizing n-paraffin hydrocarbons is described which comprises subjecting the same to the action of metallic aluminum and a chlorine containing substance capable of reacting with the aluminum to form nascent $AlCl_3$ at a temperature from about 30-400° F., said chlorine containing substance being present in sufficient amounts to combine with the exposed metallic aluminum surface and to form a coating of $AlCl_3$ thereon and also being present in sufficient excess thereover to serve as a promoter for the isomerization reaction, the reaction being carried out in the absence of extraneously produced aluminum chloride.

U.S.P. 2,344,889. Process of Isomerizing Paraffins. C. S. Lynch and J. H. Bartlett to Standard Oil Development Company

It has been discovered that halo sulfonic acids when promoted with free hydrogen with or without boron trihalides serve to catalyze the isomerization of n-paraffins to i-paraffins. The liquid catalysts are used at a temperature of 40-350° F., depending on the feed stock. Contact times of 0.5-24 hours and a hydrogen pressure of 200 pounds per square inch are employed. The amount of halo sulfonic acid employed may range between about 10 and 50 percent by volume, measured as liquid and based on the amount of reactants present in the reactor at any one time.

U.S.P. 2,344,890. Isomerization Process. J. M. Whiteley, Jr., to Standard Oil Development Company.

A straight-chain paraffin hydrocarbon containing at least 4 C atoms per mol is contacted at 75-200° F for 1-10 hours with agitation while in the liquid phase with fluorsulfonic acid and between 0 and about 200 pounds per square inch of BF_3, measured under the reaction conditions. Branched-chain paraffins are recovered from the reacted mixture.

U.S.P. 2,346,527. Isomerization. H. R. Warrick and C. W. Watson to The Texas Company

The isomerization of normal paraffin to iso paraffin and especially the isomerization of n-butane to i-butane is carried out in a plurality of reaction zones in which the catalyst varies in activity and the promoter concentration is adjusted in the zones in accordance with the activity of the catalyst The feed hydrocarbons are passed first through the zone containing the most active catalyst and then to the zone containing the next most active catalyst, and so on.

U.S.P. 2,346,768 .Catalytic Isomerization. K. C. Laughlin to Standard Oil Development Company.

Normal paraffinic hydrocarbons containing at least four C atoms per mol are isomerized by subjecting them to the action of a liquid bath of $AlBr_3$ while maintaining the reaction mixture under isomerization conditions. The temperature is maintained at about 212° F. while the pressure is sufficient to keep $AlBr_3$ in liquid phase. The presence of a hydrogen halide promoter is desirable to suppress side reactions.

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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

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Fundamental Physical And Chemical Data

Hydrocarbon Gases. E. G. SCHEIBEL AND D. F. OTHMER. *Ind. & Eng. Chem.* **36** (1944) pp. 580-83.

Nomographs and methods of calculation are presented for determining the ratio of the specific heats of hydrocarbon gases, the final temperatures attained in compression or expansion, and the theoretical horsepower requirements for compression. The mathematical procedures used depend on correlations of the physical properties of hydrocarbons, and offer a considerable simplification of the calculations that are otherwise rather tedious, and can be used within the limits of accuracy required for engineering design. The nomograph covers hydrocarbons from methane to nonane.

Critical Solution Temperatures of Paraffins with Nitrobenzene and B, B'-Dichloroethyl Ether. H. M. WOODBURN, K. SMITH, AND H. TETEWSKY. *Ind. & Eng. Chem.* **36** (1944) pp. 588-90.

Critical solution temperatures of ten paraffin hydrocarbons with nitrobenzene and six with B, B'-dichloroethyl ether were carefully determined. Several values recorded in the literature are shown to be in error. Among the normal paraffins, as the number of carbon atoms increases, the numerical difference between the critical solution temperature and the aniline point shows a steadily increasing value for nitrobenzene solutions and a steadily decreasing value for B, B'-dichloroethyl ether solutions. The data are presented in tabular and graphical form.

A Study of Organic Parachors. VII. A Series of Saturated Hydrocarbons. O. R. QUAYLE, R. A. DAY AND G. M. BROWN. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 938-41.

The parachor is one of the more useful constants in the correlation of the physical properties of organic compounds. First considered to be an additive property, the parachor has been found to be susceptible to minor as well as to gross variations in structure. Unsaturation particularly affects the parachor. The parachor values of normal saturated hydrocarbons have been found to be unique in being additive in nature. The literature of the subject is briefly reviewed. The densities, surface tensions, and parachors of a series of hydrocarbons of high purity were determined. The hydrocarbons studied included the normal paraffins from pentane to duodecane inclusive as well as several alkyl substituted paraffins. The parachor value of the CH_2 group was found to be 40.0. The atomic parachor of hydrogen is 15.5 and that of carbon 9.0. There is no apparent change in the CH_2 increment as the chain increases in length up to duodecane. The effect of branching of the chain of hydrocarbons is not constant in the saturated hydrocarbons.

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Hexachlor butadiene-1,3
Isocitric acid
Isatin beta oxime
Methyl nitrite
Ortho nitro benzaldehyde
Alpha phenyl naphthalene
Sodium salt of ethyl formyl acetate
Triiodo acetic acid
2,2', 2"-Tripyridyl
Trichlorethanol
Triethyl borine
Tribenzyl borine
Vinyl crotonate
Vinyl sulfonic acid

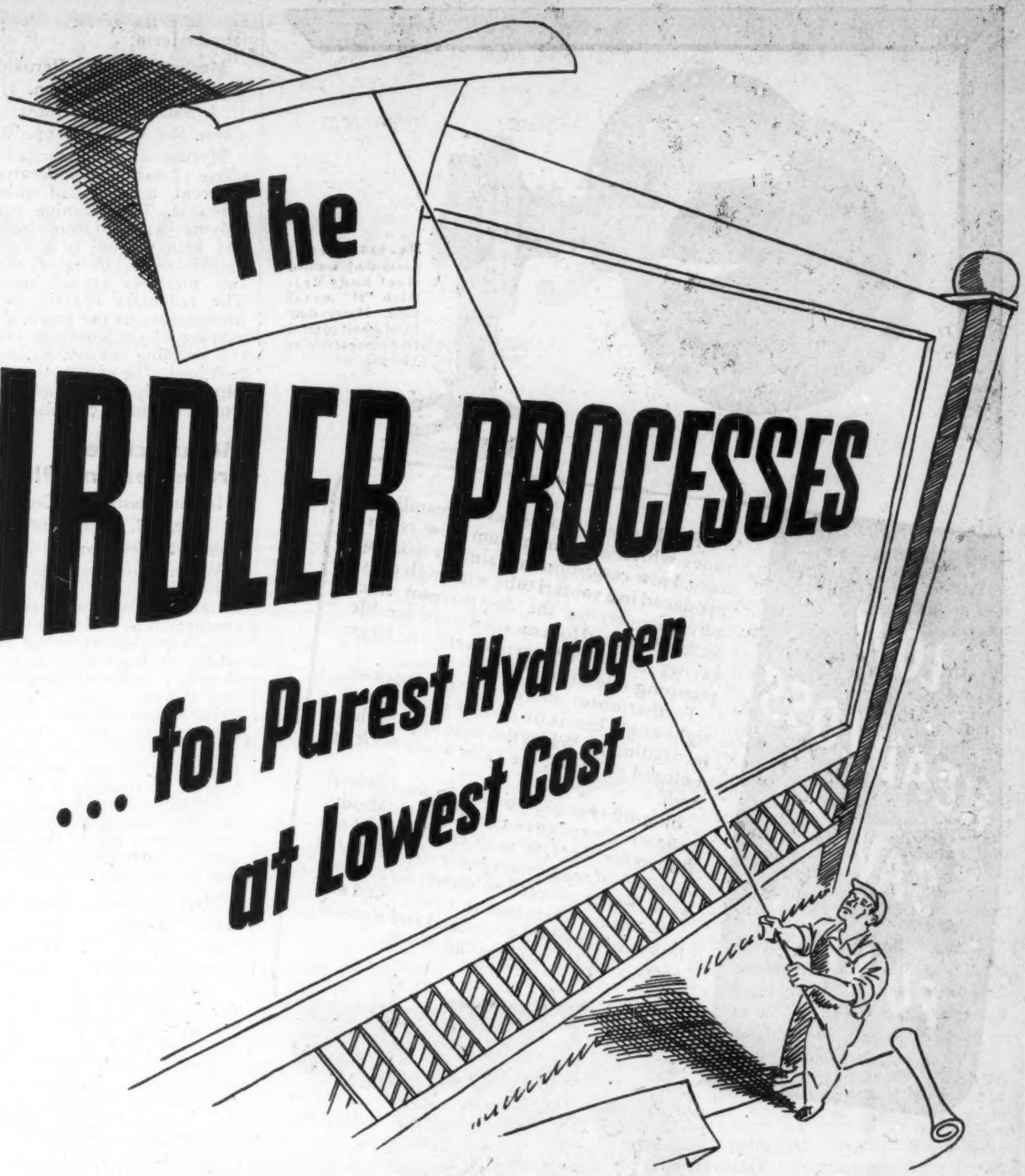
Chemical Compositions And Reactions

The Constitution of Petroleum Oils. 2. Hydrogenation Results. A. V. BRANCKER. *Petroleum* (London) **7** (1944) pp. 80-82.

The oils studied were three successive lubricating oil fractions, each of which had been separated into extract and raffinate by extraction with sulfur dioxide, and two oils free or aromatics obtained by severe acid treatment of the raffinates from two of the fractions. The molecular weight, analine point, density, refractive index, and the specific refraction were determined for these eleven oils. Waterman analyses were made from the data so obtained. The paraffin or cyclic-structured compounds were apparently not present as separate compounds. It is probable that the extract may be considered to have ring homogeneity and the rings to have alkyl groups of varying chain lengths. To confirm the applicability of the Waterman analysis, several oils were hydrogenated. Good agreement was found between calculated and experimental values.

The Reactions of Cyclohexane and Decahydronaphthalene Under Hydrogenation-Cracking Conditions. C. M. CAWLEY AND C. C. HALL. *Jour. Soc. Chem. Ind.* **63** (1944) pp. 33-39.

The process of hydrogenating coal or tar yields a gasoline that consists mainly of aromatic and saturated hydrocarbons. The saturated hydrocarbons are both paraffins and naphthenes that are largely of branched-chain type. The formation of paraffins from condensed nuclear aromatic hydrocarbons is of particular interest since it must involve ring-flooding. The authors have shown that in the presence of a suitable catalyst, cyclohexane is isomerized to methyocyclopentane, and that both compounds then undergo ring-opening, followed by the isomerization of the paraffins thus produced. The reactions of decahydronaphthalene are analogous, involving isomerization to dicyclo-nonanes and -octanes, followed by ring-opening to decanes that undergo further isomerization and degradation. Details of the



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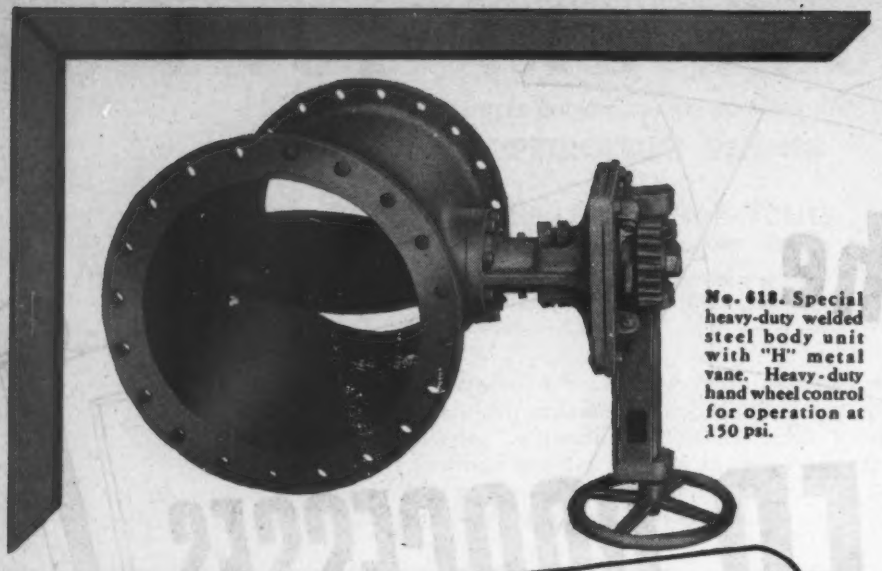

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experimental results are presented in tabular form.

Mechanism of Peroxide Initiated Styrene Polymerization. H. F. Pfann, D. J. Salley and H. Mark. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 983-5.

Styrene was polymerized in the liquid phase at various temperatures and with different amounts of p-bromobenzoyl peroxide. The bromine content of the polymer was determined gravimetrically and with the aid of a radioactive bromine isotope. The values obtained by the two methods agreed reasonably well. The polymers contain one and three bromine atoms per chain, if the viscosity average chain length is compared with the bromine content as analytically determined. The radioactive tracer method can be fairly easily applied to this problem in polymer chemistry.

Manufacture: Processes and Plant

Incompressible vs. Compressible Flow in Pipes. R. C. Binder. *Chem. & Met. Engr.* **51** (1944) pp. 99-100.

When a compressible fluid flows adiabatically in a pipe the relations are simple and well understood. Flow of a compressible fluid, however, is much more complex. It is the usual practice, when dealing with a small pressure drop of compressible fluid, to assume that the result will be close enough for engineering purposes, and apply the incompressible fluid laws. The author shows mathematically just how different the two relations are and what errors may be introduced if the simpler law is used for gases at high velocity or at large pressure drop. A chart is presented that enables use of the simpler relation, with the introduction of a correction that can be obtained from the chart.

Heat Transfer Coefficients in Agitated Vessels. T. H. Chilton, T. B. Drew and R. H. Jebens. *Ind. & Eng. Chem.* **36** (1944) pp. 510-516.

An extension of the general method for correlating forced-convection heat transfer data is proposed for the case of a coil and the inside surface of a vessel in which the fluid is agitated by a flat paddle. The method of correlation for conduits and for plane surfaces has been found applicable to agitated vessels. The correlation is found suitable for the turbulent region of agitation, up to the point at which gas is drawn into the liquid. Four liquids were used in the experimental work, including water, two oils and glycerol. The temperature difference across the heat transfer surface was varied over a wide range. The correlations obtained approximate the data of several investigators for agitated systems considerably different from those used in the experimental work. The experimental equipment used in the work is described in some detail and the procedure is outlined. Results are presented in detail in tabular and graphical form.

Improving Solids—Gas Contacting by Fluidization. J. C. Kalbach. *Chem. & Met. Engr.* **51** (1944) pp. 94-8.

Development of the fluid catalyst process for aviation gasoline manufacture has aroused interest in the possibilities of achieving better solids-gas contacting for a variety of purposes by the use of "fluidized" solids. The author

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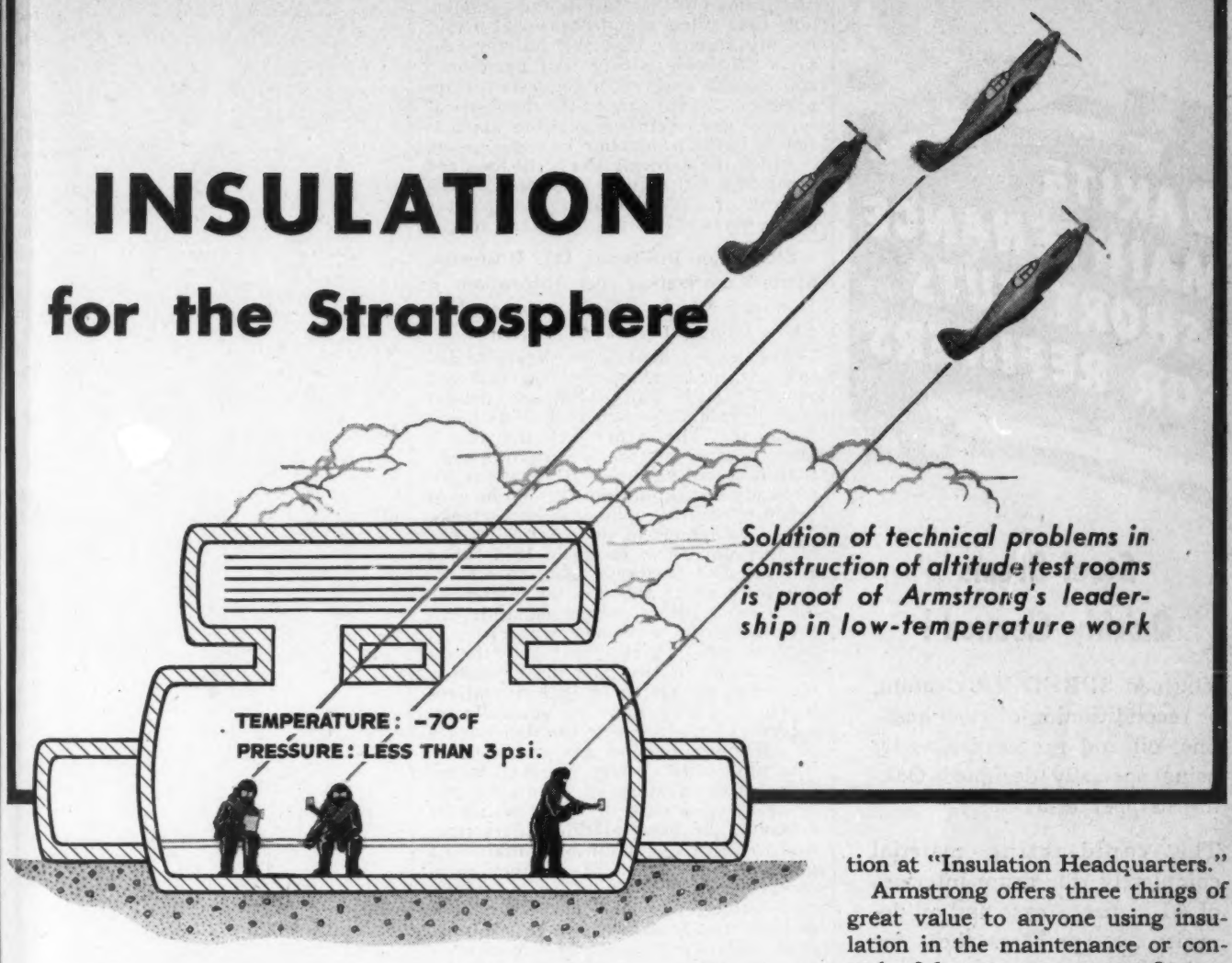

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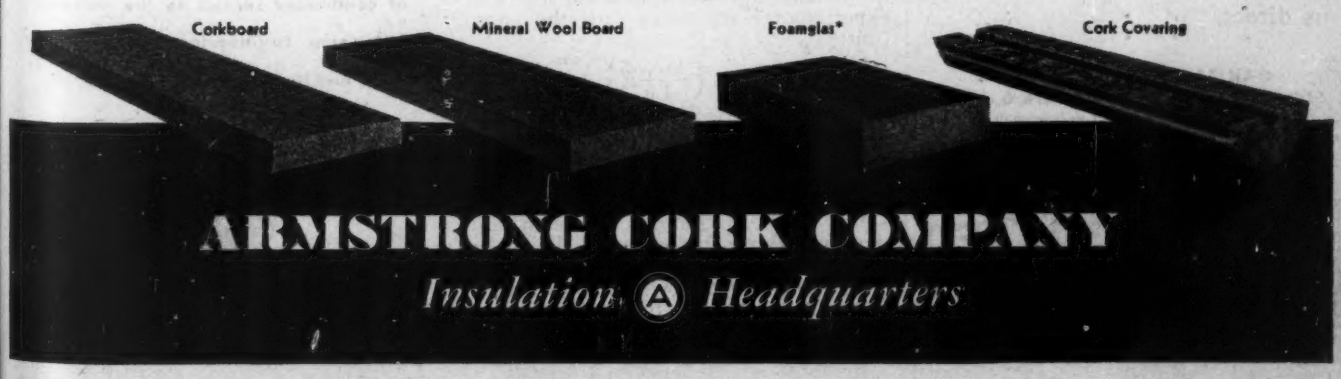

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traces fluidization processes back to their first appearance in the patent literature, and points out that despite the considerable time it has found occasional use, it is only recently that the full implications of the fluidizing tool have been recognized. The author suggests the application of fluidizing to the desulfurization of gas. Another possible application is in the production of sponge iron, in which the reducing gas is the fluidized medium for the finely divided particles of iron ore. A bibliography of patents and references is appended to the article.

Studies in Diffusion: III. Unsteady-State Vaporization and Absorption. J. HOWARD ARNOLD. *Trans. Amer. Inst. Chem. Engrs.* **40** (1944) pp. 361-78.

The development of the theory of diffusional unit operations has centered around the two-film mechanism, steady-state diffusion through such films being postulated. The author feels that this is more because of comparative simplicity than correctness, and that equations for unsteady-state conditions should be used because of their physical correctness. The development of an analytical theory of diffusional flow began in 1855, when Fick applied Fourier's equation for the flow of heat to the flow of matter by diffusion. A more correct equation, allowing for the movement of both components, was derived from kinetic theory by Maxwell in 1866 and the derivation simplified by Stefan in 1871. Equations based on Fick's Law are generally incapable of representing the dependence of diffusion rates on gas composition. The physically correct Maxwell-Stefan differential equation is solved for the unsteady-state case of the semi-infinite column. The new solution differs from that for Fick's equation by containing a parameter ϕ, which is a function of composition. For simplicity, a correction factor F for the Fick equation is deduced and accurately computed values of ϕ and F are given for vaporization and absorption. Experimental data for vaporization and absorption are correlated satisfactorily by the use of these factors. The new equations are also used as the basis for an unsteady-state method of measuring diffusivities of vapors through gases.

Film Coefficients for Condensation of Organic Vapors on a Single Vertical Copper Tube. E. M. BAKER AND H. HIPKIN. *Trans. Amer. Inst. Chem. Engrs.* **40** (1944) pp. 291-308.

Film coefficients for the condensation at atmospheric pressure of mixed heptane 95 percent alcohol, benzene, and acetone were determined experimentally using an apparatus described in a previous paper. All determinations were in the range of viscous flow. The measured coefficients agreed, within the limits of experimental accuracy, with the equation:

$$h = 1.13 \left(\frac{k_t^3 p_t^2 g_\lambda}{L u f \Delta^t} \right)^{0.25}$$

which equation is 20 percent higher than the theoretical Nusselt equation. This equation was previously recommended by McAdams for condensation on vertical tubes, on the basis of experimental steam data. In commercial steam condensers, the steam-side coefficient is generally so large that the water-side coefficient controls, whereas in condensing organic vapors the vapor-side coefficient controls at usual water velocities. The equipment is briefly described,

A view of one of many plants designed and constructed by Petroleum Engineering, Inc., in the past 15 years of continuous service to the industry. *Petroleum Engineering, Inc.*, Offices: Tulsa and Houston.

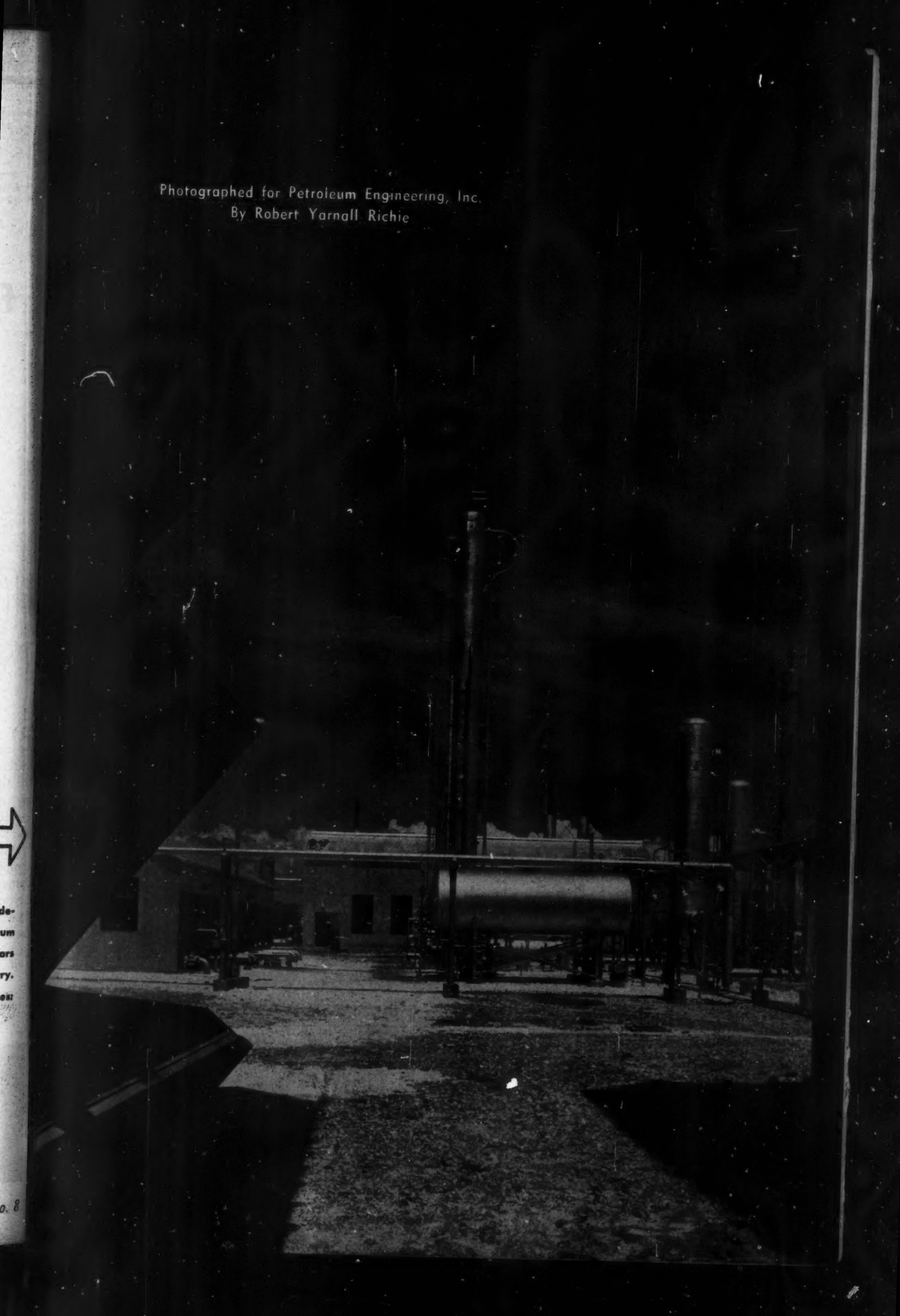

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Fig. 16
"Renewo" Globe

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Fig. 2125
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Fig. 1430
Iron Body Gate

Fig. 1938
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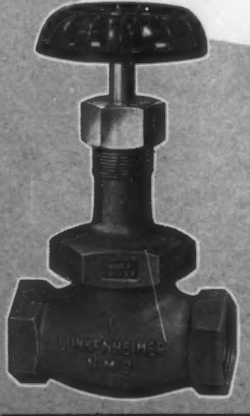

Fig. 123
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and the tube calibrations and procedure in the tests is outlined. Data secured in the work are presented in detail in tabular form and are also shown as graphs.

Stagewise Operations — Applications of the Calculus of Finite Differences to Chemical Engineering. F. M. TILLER AND R. S. TOUR. *Trans. Amer. Inst. Chem. Engrs.* **40** (1944) pp. 317-32.

The stagewise operations of plate fractionation, plate gas absorption, and multiple contact extraction are used in many chemical engineering processes. The mathematical treatment of these processes is simplified by the use of the calculus of finite differences. This branch of calculus deals with the laws governing the ratio of finite differences in contrast to the differential calculus that deals with the limit approached by this ratio as Δx becomes infinitesimally small. The paper presents some of the elements of differencing, summation, and difference equations. These have close parallels in differentiation, integration, and differential equations. Applications to the solution of problems arising in gas absorption, countercurrent washing, fractionation, and the rectification of data are included.

Gas-Liquid Contacting by Mixers. H. C. FOUST, D. E. MACK, AND J. H. RUSHTON. *Ind. & Eng. Chem.* **36** (1944) pp. 517-522.

Results are presented on the dispersion of air in water by means of a disperser-type mixer. The amount of air retained in bubble form in the liquid in a cylindrical tank filled with water has been measured and is considered to be useful in estimating the ability of mixers to disperse gases in liquids. A term called "contact time" has been calculated and is related to power input and air velocity for one ratio of tank to impeller diameter. In the experimental work vessels from 1 foot in diameter to tanks 8 feet in diameter were used. The tanks were baffled, and the disperser was rotated on a vertical shaft located on the axis of the tank. Liquid quantities involved ranged from 5 to 2250 gallons. The air flows ranged from 1 foot per minute superficial velocity to 5 feet per minute. Power was measured over a range of 0.01 to 6.5 horsepower. Over this wide range of conditions a general relationship was found to hold, namely, $h/f = \theta = c(hp.)^a/VF$. Several positions of the impeller with respect to liquid depth were studied. The data should prove to be useful in predicting gas dispersion as a function of the power input. Relations are given showing how to handle larger or smaller volumes of gas in order to achieve equal, lesser, or greater contact time. Data are included to show the effect of air flow on the power consumed at different impeller speeds. The data secured in the work are presented in detail in tabular and graphical form.

A Mass Velocity Theory for Liquid Agitation. F. D. MILLER AND J. H. RUSHTON. *Ind. & Eng. Chem.* **36 (1944)** pp. 499-503.

The selection and application of liquid agitators is at present an art rather than a science. Some work has been done in an effort to place agitation on a scientific basis. Much of the work done has concerned specific agitators and their applications and has contributed little to

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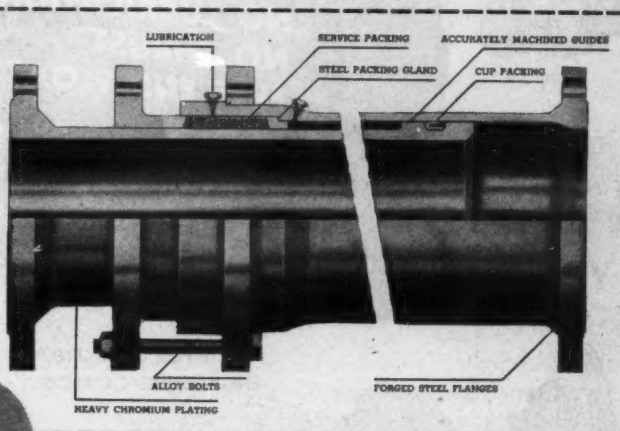

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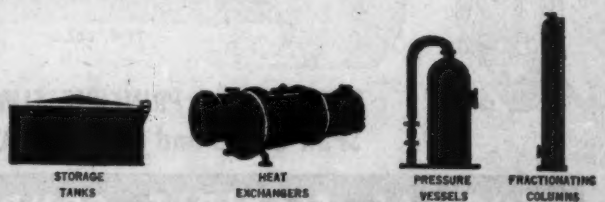

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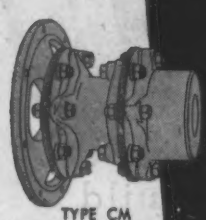

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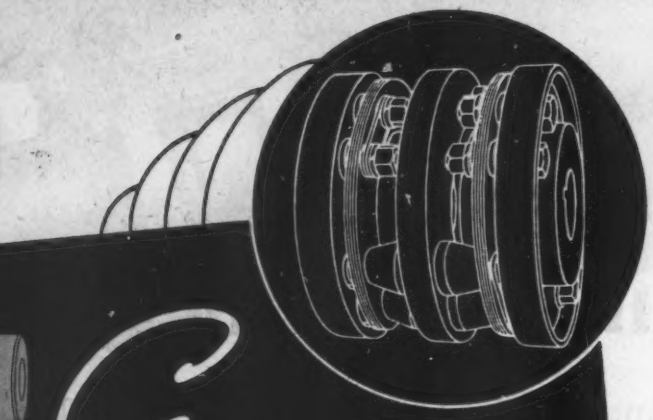

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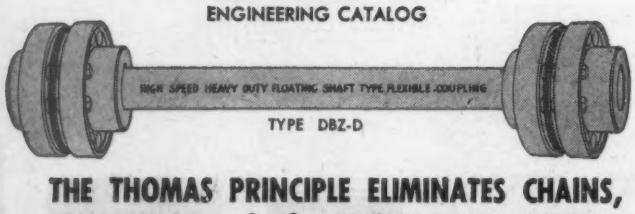

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the fundamental principles of the problem. The authors suggest that agitation may be studied from the standpoint of two separate interrelated actions: (1) those characteristic of the impeller and stream discharged by it, and (2) those dependent upon the nature of the fluid flow required to produce the desired result in the fluid. The first is the result of impeller performance; the second determines the agitation requirement. The action of an impeller produces a definite mass flow; the amount and speed of flow required for a given result are controlled by the physical properties of the fluids, solids, or gases to be handled. The three performance characteristics of impellers are discharge capacity, discharge velocity, and power requirement. Data are given showing the relationship of discharge characteristics and power required for several types of propellers. These are general and well established. Methods for the evaluation of impeller performance and the action of the discharge stream are proposed. Means for evaluating agitation requirements are discussed. Examples are given for operations such as maintaining or producing suspensions. These indicate how an impeller can be selected to produce a desired result once the agitation requirements are determined.

The Coming Search for Synthetic Motor Fuels. J. L. MARSH, G. H. FREMON, R. D. GLENN, V. D. LUEDEKE, AND D. J. PORTER. *Chem. & Met. Engr.* 51 (1944) pp. 107-11.

The Senate has authorized expenditure of $30,000,000 to develop processes for obtaining motor fuels from coal, shale and forest products. This is necessary, for another world war might bring a crisis suddenly and make synthetic gasoline as vitally important as synthetic rubber is today. It may be desirable to begin the use of these other fuels long before the supply of petroleum becomes critically short. Therefore, it is of interest to consider the methods that are available for the production of motor fuels from sources other than petroleum. The experience of other countries that are already making synthetic fuels may point the direction in which developments in America will occur. Sources of fuels, including oil shale and tar sand, coal, synthetic fuels from coal gases, the Fischer-Tropsch synthesis, and catalytic procedures are discussed by the author. The opinion is expressed that the supply of motor fuels from petroleum will be assured for the next twenty-five to fifty years. Carbonization processes will yield small amounts of gasoline but cannot be expected to produce significant quantities. Shale is the most promising source, and will be developed as soon as the cost of petroleum rises to $2 a barrel. If the shale resources of the country were developed enough oil could be produced to supply the country for another fifty years. Tar sands, too, offer a source of large amounts of oil that can be recovered cheaply. Synthetic fuels from coal are at present expensive and the cost of plants to produce the fuels is high. Until the processes are improved there will be no economic incentive to use them. It is concluded that it seems unlikely that there will be large scale production of synthetic fuel from coal in this country in the near future.

Butane Dehydrogenation. C. C. WATSON, F. NEWTON, J. W. MCCAUSLAND, E. H. MCGREW, AND L. S. KASSEL. *Trans.*

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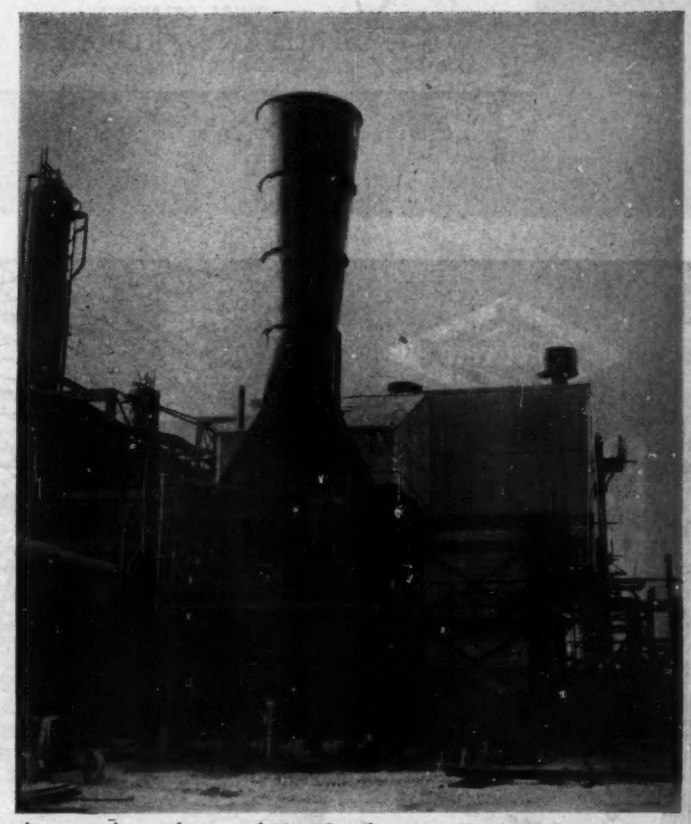

A rear view of one of the Combustion Engineering units as installed showing economizer, fans and stack.

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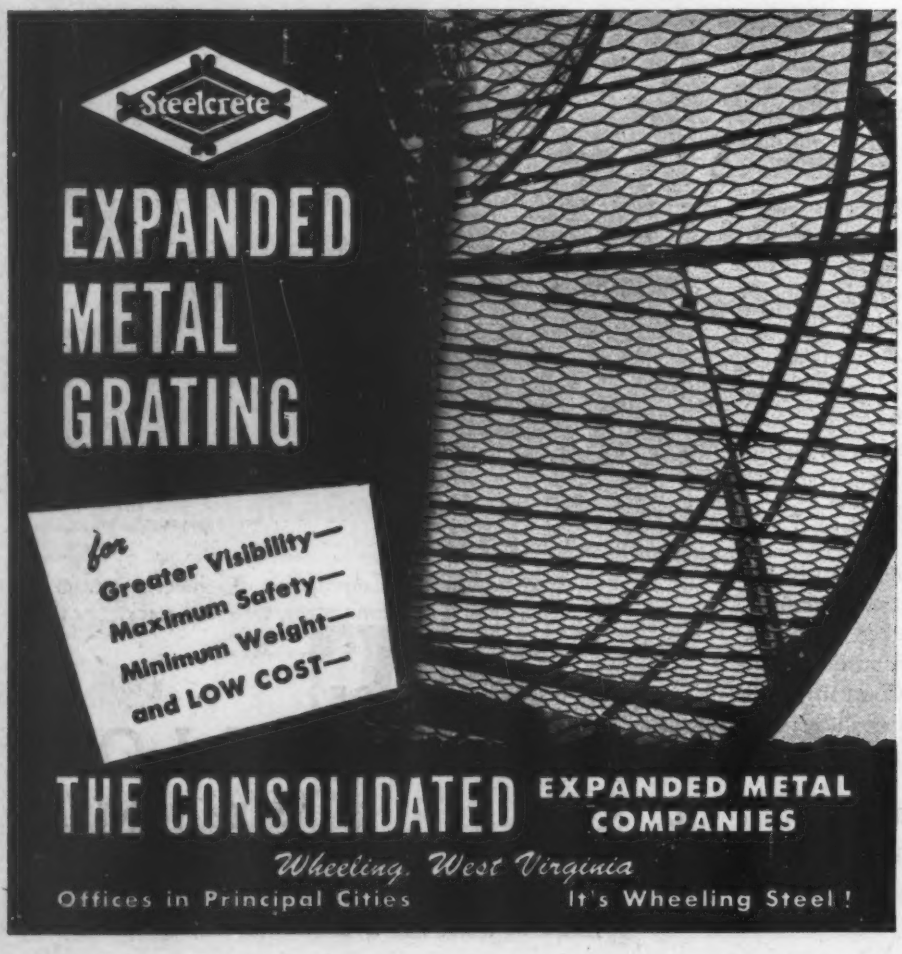

Amer. Inst. Chem. Engrs. **40** (1944) pp. 309-315.

The dehydrogenation of butane is effected catalytically because, without the use of a catalyst the rate of conversion is low and the yield of degradation products high. Carbon deposits on the catalyst, and the catalyst must be regenerated by treatment with oxygen-containing gas whereby carbon is burned. The temperature during regeneration exceeds that in operation and thus imposes a severe requirement on the thermal stability of the catalyst. The temperature used in dehydrogenation must be above 950° F., for below that temperature the thermodynamic equilibrium is such that conversion is low. The temperature coefficient of the catalytic reaction is less than that of the reactions of thermal cracking and the catalytic reaction rate increases less than proportionately with pressure. Decrease of pressure is favorable to reaction. Major factors in plant design are the high endothermic heat of reaction, the exothermic heat of regeneration, and the desirability of a moderately low pressure drop, so that the entire catalytic zone can be operated in the low pressure range. Heat must be supplied during the reaction, for the heat of reaction is about 1000 B.t.u./lb. and the corresponding temperature drop in the adiabatic system would be 300°-400° F. whereas the operating range is only about 100° F. The heat exchanger type of reactor is therefore used. The temperature during regeneration does not exceed a safe maximum of approximately 1300° F. The design of the catalyst tubes is of major importance. The reasons for this are discussed. Tubes are made of a special alloy steel. A simplified flow diagram of a plant is given and the operation described.

Experimental Study of Azeotropic Distillation—Use of Trichloroethylene in Dehydration of Ethanol. A. P. COLBURN AND J. C. PHILLIPS. *Trans. Amer. Inst. Chem. Engrs.* **40** (1944) pp. 333-59.

The purpose of the study was to obtain plate-to-plate compositions and temperatures in an experimental investigation, and to interpret these data in terms of a general design procedure for multicomponent non-ideal distillation applicable in the usual case where complete multicomponent equilibrium data are not available, but equilibrium data for pairs of components are known or are readily obtainable. Ethanol and water were distilled in a 15-plate column with trichloroethylene as a carrier. Continuous operation was effected by mixing the overhead and bottoms streams and introducing the mixture as feed. The work showed that water is readily distilled from alcohol when sufficient entraining agent is present to be fairly rich on the feed plate, but that when the agent is dilute on the feed plate, water was present in the alcohol leaving the bottom of the column. From observed liquid compositions and temperatures and from vapor compositions calculated from operating equations, experimental vapor-liquid relationships existing in the column were determined and expressed as activity coefficients. These were in fair agreement with predicted values based on the known vapor-liquid equilibrium data for the two binaries, thereby supporting an approximate but convenient design procedure for multicomponent non-ideal systems. The apparatus and

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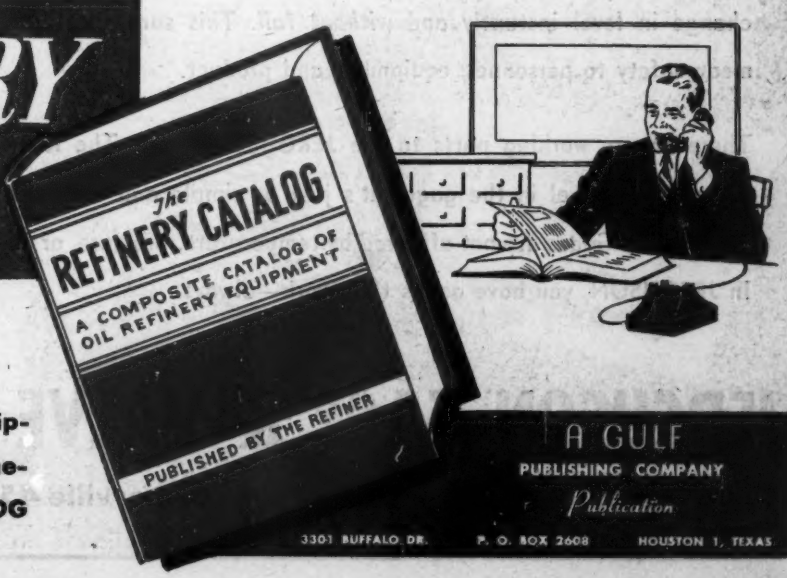

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procedure used in the work are described and the data obtained are presented in considerable detail in tabular and graphical form.

Products: Properties And Utilization

Progress in Gas-Burning Diesel Engines and Plants. ROBERT CRAMER, JR. *Mech. Eng.* **66** (1944) pp. 369-72.

Experiments in using gas as diesel fuel were first conducted in March, 1928, using a 3-cylinder, 2-cycle, 560 h.p. air-injection diesel engine and 520 B.t.u. manufactured gas. The experiment showed that gas would ignite and burn satisfactorily in the diesel cycle. Ignition was "bumpy" on gas alone but this difficulty could be avoided by injecting a small amount of fuel oil with the gas. Gas-diesel engines producing more than 99,000 h.p. in the aggregate, in unit sizes from 1000 to 3600 brake horsepower are now in daily operation using natural gas as fuel. Air-injection engines representing over 15,000 h.p., and now running on fuel oil, can be converted to burning gas when natural gas is available at low cost. Performance data on a 2430-h.p. gas-diesel engine are given. The average fuel cost of 2.35 mills per kilowatt hour, and the average fuel consumption was 11,579 B.t.u. per kilowatt hour.

The Contamination, Deterioration, and Decomposition of Lubricating Oils in Service. R. G. POMEROY. *Jour. Inst. Petr.* **30** (1944) pp. 95-133.

The object of the author is to assist users to obtain a better understanding of the composition and deterioration of lubricating oils, and to indicate the type of deterioration to be expected in the operation of the more common items of equipment found in plants. Chemical composition and structure of mineral lubricating oils is briefly considered. Under discussion of the deterioration of oils the author considers factors that accelerate oxidation, products of oxidation, tests for acidity, polymerization, thermal decomposition, emulsification, electrolysis and electrical phenomena, corrosion, possible effects of paints and pipe-jointing compounds, foaming and vaporization, the blending of oils, and sludge and deposits. Inhibitors are briefly considered. Contamination, deterioration, and decomposition to be expected in different types of equipment are reviewed, including those typical of air compressors of the reciprocating type, gyratory crushers, gear-boxes, circulatory systems of electrical machines, hydraulic systems, internal combustion engines, refrigerators, steam engines, and steam turbines. The treatment of oil in service and the reclamation of used oil is briefly discussed, including removal of oxidation products, sweetening, breaking of emulsions, dehydration, coagulation of colloidal carbon, removal of diluents, improvement of color, and types of filters including gravity, centrifugal and magnetic filters and filter presses.

Bitumen-Aggregate Adhesion. J. M. SWANSON. *Ind. & Eng. Chem.* **36** (1944) pp. 584-88.

An important factor in the service life of a bituminous road matte is the ability of the bituminous material to resist the stripping action of water. The object of the work described in the paper was to survey the possible approaches to the

Quality up, cost down

Doctor sweetening was used in a western refinery to remove mercaptan odor from gasoline It did that, but it also caused considerable loss of gasoline, degraded the octane rating and reduced lead susceptibility so low that Ethyl grade gasoline could not be made

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A Unisol treating plant, costing $20,000, proved a mighty good investment

Gasoline treating loss has been cut almost to zero Unleaded octane rating, instead of being degraded, has been raised half a point Lead susceptibility has been so improved that 3 cc of tetraethyl lead now produces gasoline of 80 plus octane rating

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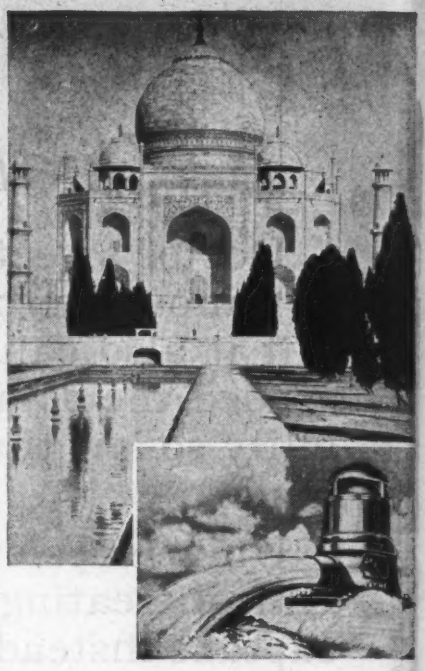
problem of increasing the bitumen-aggregate adhesion, to select promising methods, and after determining the optimum conditions for its practice to evaluate its effectiveness under field conditions. It was considered that any treatment should permit the use of water wet-aggregate, should prevent the stripping of the bitumen from the aggregate by water after placement of the matte, and should be economically feasible. Specific modifications of the general method suggested by McLeod, namely that of treating the aggregate with solutions of a heavy metal salt and a soluble soap in such a way as to produce a coating of insoluble soap that is better wetted by bitumen than water, have been developed as promising for practical road construction. This type of treatment has been applied to plant mixes, and the process tested on a small scale in the field. Details of the procedure are presented. The successes and failures of the road panels are briefly considered. In general, the research showed that bituminous materials can be made to coat water-wet aggregate to produce a highly water-resistant mix at a reasonable cost by a modified McLeod type of treatment. As developed, the treatment may have possibilities of application in road construction where uniformly thin mattes can be laid and adequate drainage assured. In special applications where a water-resistant mixture of bitumen-coated aggregate is desired and where the plastic properties of the mass is not a problem, the treatment should be useful.

Instruments for the Determination of Specific Gravity of Gases. R. M. CONNER. *Am. Gas Assoc. Monthly* **26** (1944) p. 252.

A committee was organized at the National Bureau of Standards for testing the effectiveness of various instruments for the measurement of the specific gravity of gases. Fifteen gases and gaseous mixtures were used in the study, and instruments of recording and indicating types in common use were studied. Eleven instruments, contributed by seven manufacturers, were used in the work. The instruments were considered in groups according to the type involved and the corrections applicable. No opinion is expressed with reference to the relative merits of the instruments because of the widely varying conditions for which they are designed. Some are portable and designed to give quick and approximate values, others are designed to give high accuracy. A number of improvements and suggestions for further developments were indicated to the manufacturers. A complete report on the work will be published at a later date by the Bureau of Standards.

Analytical Determination of Aromatic Hydrocarbons by Absorption. B. J. MAIR AND A. F. FORZIATI. *J. Res. Natl. Bur. Standards* **32** (1944) pp. 151-64.

The aromatic hydrocarbon content of a solution of hydrocarbons such as the gasoline fraction can be determined by a simple adsorption process. When a solution of mixed hydrocarbons is filtered through an adsorbent, the filtrate consists first of a portion containing no aromatics, second a portion intermediate in composition, and then the original solution. The intermediate fraction can be proportioned between the first and third fractions so that the amount of aromatic-free material can be determined as if there had been a sharp



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Nor need any one in the Layne Organization preach the superior merits of Layne Water Systems or of Layne High Efficiency Pumps. They need only to point to any of many thousands now in operation and say—"go and see for yourself." This long used policy places all responsibility directly upon the product itself.

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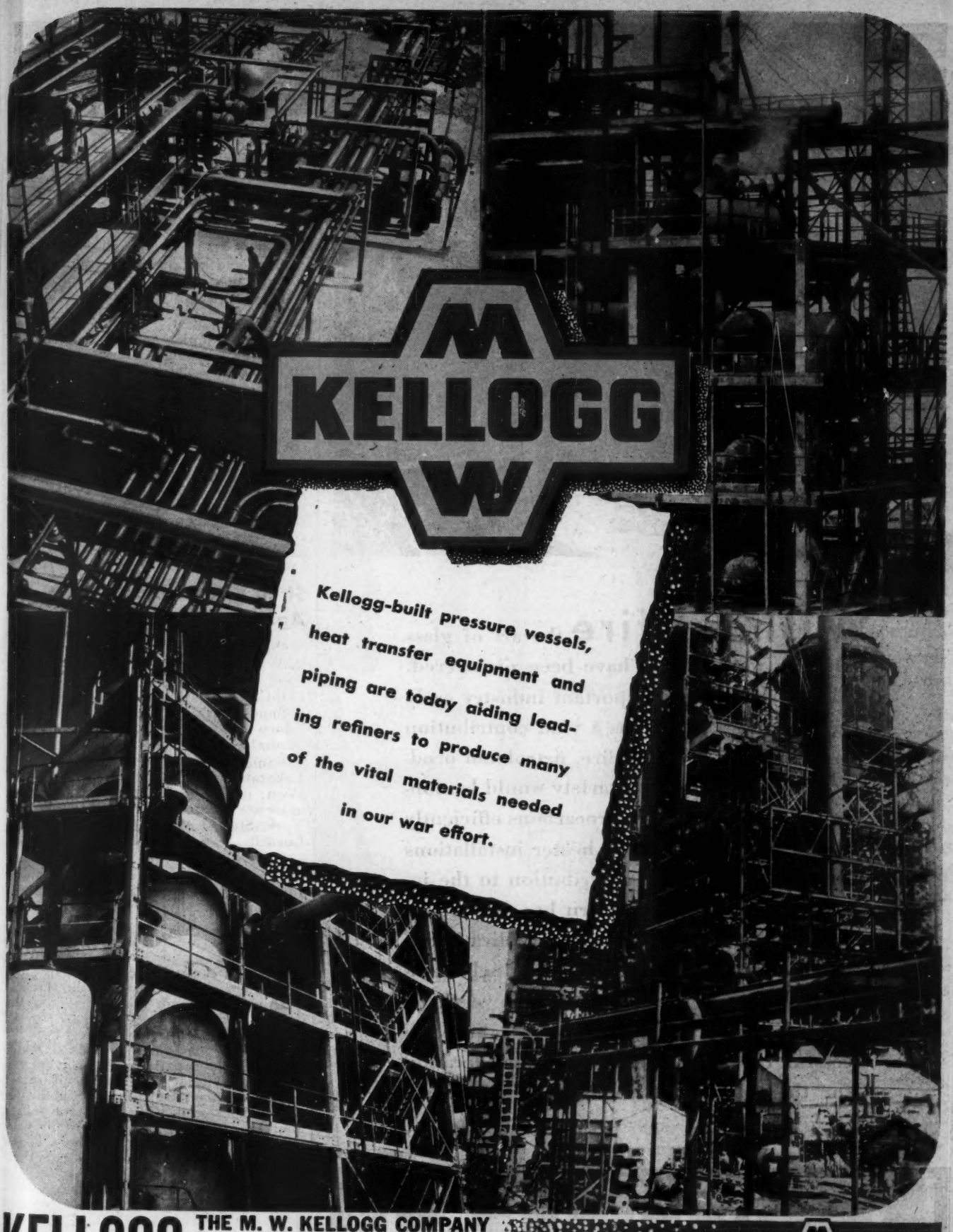
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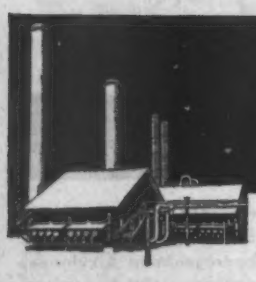

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break between the first and third fractions. The concentration of aromatics is determined by use of a calibration curve established from experiments on known solutions with the standard adsorbent. The apparatus and procedure are described.

A Vacuum Stopcock Lubricant Unaffected by Hydrocarbons. W. H. PEARLSON. *Ind. & Eng. Chem., Anal. Ed.* 16 (1944) p. 415.

The author prepared a stopcock lubricant that is unaffected by hydrocarbons and suitable for vacuum work. The cellulose acetate was cut into small pieces and 7.5 grams dissolved in 45 grams of tetraethylene glycol. After 4 hours at 140° C., with frequent stirring, the solution was homogeneous. 30 Grams of citric acid was heated on an oil bath to 190° C. and the cellulose acetate solution added to it. Heating was continued at 180-190° C. for 90 minutes. Dissolved water was removed by evacuation in a desiccator. Stopcocks lubricated with this material, which is essentially a glycol citrate polymer containing cellulose acetate, showed no signs of failure after 6 months in contact with liquid toluene, repeated evacuation, and frequent stirring. The lubricant does not change in properties upon storage in a closed jar.

Shell Establishing Plant for Agricultural Research

Shell Oil Company, in cooperation with Shell Development Company and Shell Chemical division of Shell Union Oil Corporation, will establish a half-million dollar, 142-acre agricultural laboratory at Salida, six miles north of Modesto, California.

Named to head the Shell Agricultural Laboratory, the first of its kind in the West, is Dr. T. R. Hansberry, former associate research professor of the New York State College of Agriculture at Cornell.

Experiments will be made in the fields of spray oils, fertilizers, insecticides, fungicides, soil and grain fumigants and plant hormones.

Shell Oil Company and Shell Chemical manufacture farm sprays, orchard sprays and liquid ammonia fertilizer; while Shell Development Company has, at Emeryville, California, the largest petroleum research laboratories on the Pacific Coast.

On the staff of the project will be outstanding men in the fields of entomology, plant pathology, plant physiology, nematology and horticulture.

Present plans call for construction of green houses, a laboratory and office building, including an auditorium with motion picture equipment where growers can meet for discussion of their problems.

The project will employ more than thirty persons.

Cragin Quits Washington

Robert B. Cragin has resigned as assistant director of the refining division of PAW at Washington to return to The M. W. Kellogg Company. He had been with the agency since 1941 and was in on the start of the aviation gasoline expansion program.

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If this Housing ever Breaks or Distorts we will replace it Free
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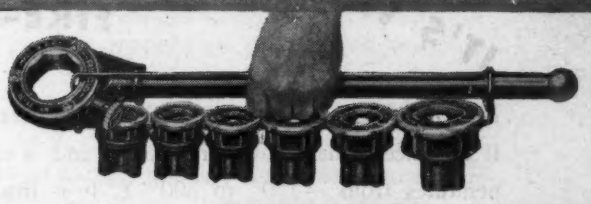
Heads snap in from either side . . . can't fall out



• For quick, easy, clean-cut threading you can't beat this small work-saver RIDGID. Separate internal-ratchet die heads snap into ratchet ring from either side—can't fall out. You simply reverse dies for close-to-wall threads—no special dies needed. Furnished with patented carrier in any combination of sizes: No. 11R, 7 sizes from $\frac{1}{8}$ in. to $1\frac{1}{4}$ in.; No. 0R, 6 sizes from $\frac{1}{8}$ in. to 1 in. Rugged, fast, very satisfactory—try them at your Supply House.

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Koldboard will not support combustion and it resists the infiltration of moisture, conceded to be the greatest contributory cause of low-temperature insulation failure. It will not disintegrate, decay, or break down structurally under severe service conditions. Send for sample and catalog. *Baldwin-Hill Co., 567 Klagg Ave., Trenton 2, New Jersey. Plants in Trenton, N. J., Kalamazoo, Mich., and Huntington, Ind.*

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HEAT & COLD INSULATIONS

Metals Which Stand Heat And Humidity Best

Effect of high temperature and humidity on the corrosion of metals and tests showing those which stand up best, were discussed in a paper before the American Society of Mechanical Engineers at Pittsburgh, June 21, by W. L. Maucher and B. W. Jones of General Electric Company, Schenectady, New York.

Four groups of 18 selected metal specimens were subjected to combined high temperature and high humidity to test the effects of the corrosive atmosphere in a refinery along the Gulf Coast. Such an atmosphere attacks various metals very actively, it was said. The tests covered two groups of metals located indoors and two out of doors for about 18 months.

"Various metals when subjected to the combination of high temperatures, high saline humidity, and to the gasses which are found around and in the various oil refineries along the Texas Gulf Coast exhibit a very high rate of corrosion," the paper stated. "This condition has been the cause of much destruction to enclosing cases, structural members, and to electrical parts which are magnetic."

The tests led to these conclusions:

1. Of the four electro plated coatings on copper, the tin appeared to stand up best. The cadmium was completely gone and the silver showed heavy attack as evidenced by the scaly black deposit which was probably silver sulphide. The lead plating did not look so bad on the surface but on closer inspection, deep pits of the copper base metal were noted.

2. Rating the chromium alloys in their order of merit, 18-8 stainless steel and Nichrome V average up about the same and rate about the best in this test. The 25-percent-chrome steel was somewhat worse and the 12-percent-chrome steel was decidedly inferior.

3. While aluminum, untreated, showed a uniform corrosion coating and the anodized aluminum had scattered pits, this metal showed up nearly as well as the 18-8 stainless steel. Considering price, it was the consensus of opinion that aluminum, anodized for otherwise properly treated for paint, and then given two or more coats of suitable aluminum paint, would provide one of the most-corrosion-resistant combinations.

4. The test on copper and copper alloys showed conclusively that the high-copper metals have a low resistance to corrosion in this kind of atmosphere and should not be used unless protected by some protecting coating.

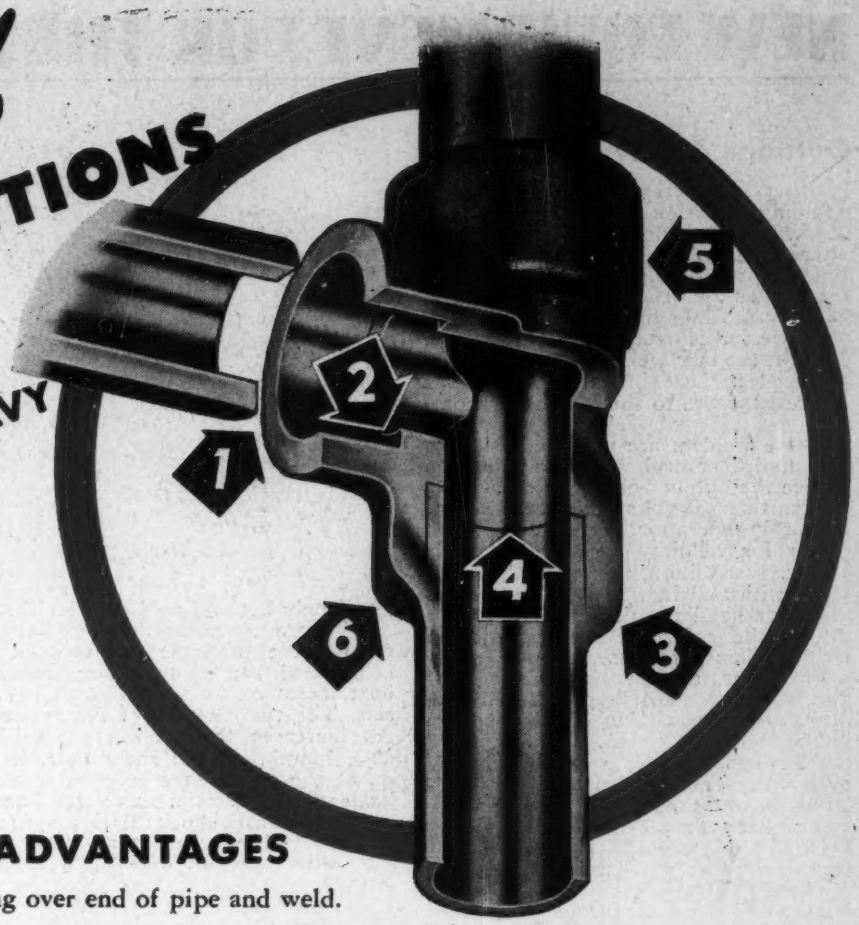
5. A comparison of monel and nickel indicate that nickel was not attacked as much as was monel.

6. The extremely bad corrosion of the unprotected cold-rolled steel indicates the severity of the corrosive atmosphere at this location and emphasizes the neeessity for maintenance painting on any steel parts.

7. Lead showed up outstandingly well but because of its low physical properties would not lend itself to many applications.

8. The interesting observation on silver was that although it was heavily attacked there was no sign of pitting or noticeable etching. The metal underneath the corrosion film was very smooth. On large knife switches the silver surfaces continued to carry their currents satisfactorily.

Speed PIPE CONNECTIONS ON STANDARD EXTRA HEAVY AND DOUBLE EXTRA HEAVY PIPE LINES



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- ***Deep Socket***—supporting and aligning the pipe, eliminates tack welding and the use of special fixtures. Accurate measuring and cutting of pipe unnecessary —Ample come—and—go.

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- ***Smooth Flow***—assured as inside diameter of fitting matches inside diameter of pipe.
- ***Long Bands***—extending well beyond bottom of socket, provide ample reinforcement, eliminating weak sections.
- ***Strong, Trouble-free Joints***—the fitting and pipe are fused into one integral unit permanently tight and leak-proof. Unaffected by vibration, distortion and shock.

W-S Forged Steel Socket Welding Fittings are machined from solid drop forgings. Available for use with Standard Pipe—Schedule 40 Extra Heavy Pipe—Schedule 80 and Schedule 160 Pipe, and Double Extra Heavy Pipe. Sizes ¼" to 4" I.P.S. Each class can be furnished in Carbon Steel; Carbon-Molybdenum Steel; Chromium-Molybdenum, Steel or Stainless Steel. Conform to ASA Standards. Ask for Bulletin A-3.

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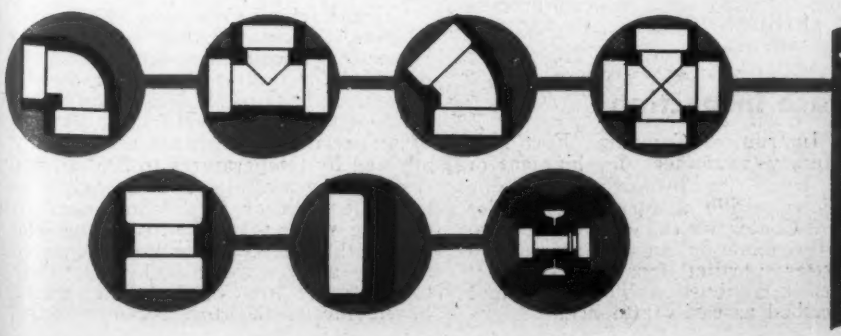

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Outdoor A-C Welders

General Electric Company, Electric Welding Division, Schenectady, New York, has announced two new outdoor alternating-current welders, a 500-amp type and a 300-amp type. The 500-amp welder has a current range from 100 to 625 amps, while the range of the 300-amp welder is from 60 to 375 amps. Both of the new welders are specifically designed for use in outdoor locations where exposure to the weather is common.

These welders are equipped with an "idlematic" control which functions to reduce the output voltage automatically to less than 30 volts whenever the arc is not in operation, yet provides full power for welding directly the arc is struck. In addition, this control is provided with a switch, conveniently operated by a handle projecting through the top of the case, for shutting off the welder when not in use.

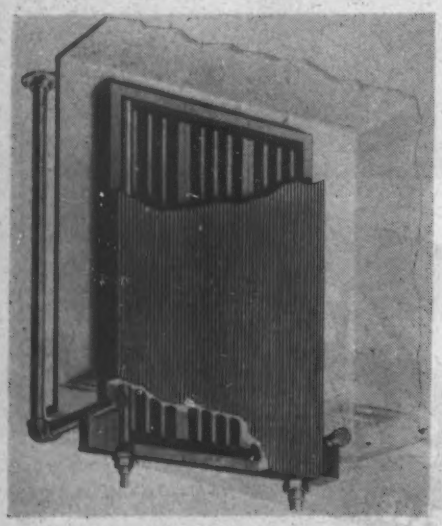
Protection against the entrance of rain, snow, and sleet is provided by the drip-proof construction of all openings in the top of the sturdy enclosures of the welders, and by a sealed window over the current indicator. The ventilating openings serve both to shed water and to keep air velocity low. A special finish on all internal parts provides protection against corrosion from moist air.

These welders also incorporate features of General Electric Company indoor a-c welders of this type, including built-in power-factor improvement, fingertip adjustment, stepless current control, and fian-forced ventilation.

G-E Welder

Heat Exchanger

National Carbon Company, Carbon Products Division, Cleveland 1, Ohio, announces a heat exchanger made of "Karbate" chemically inert graphite materials, for use in chemical and process industries. Designed specifically for chemical applications, the corrosion-resistant "Karbate" heat exchangers possess high heat rtansfer values and are resistant to practically all acids, alkalis and solvents. They are unaffected by acute thermal shock and may be used freely in intermittent operations, or in alternately hot and cold chemical baths.



"Karbate" Heat Exchanger

Of plate type, the heat exchangers employ the principle of extended, or corrugated, surface to attain maximum heat transfer area within small overall size. The compactness of the exchangers increases their inherent mechanical strength. At the same time, it reduces the tank space required for the heaters, further minimizing the hazard of mechanical shock during process operations. The heater is a 4-inch thick plate with a number of internal 1½-inch diameter communicating channels for steam or cooling medium.

Standardized production of the heat exchanger units is in four design groups, incorporating both parallel and series-flow channels, thus making possible 30 different combinations to meet the widest range of heating and cooling requirements. The heaters may be installed in sections, depending upon tank capacity or solution temperatures required, and are suitable for nearly all tank sizes or shapes.

A number of the heat exchangers have been in use in various processes for a year or more and afford sufficient service data for comparative purposes. Such heaters, 4 x 10 x 48-inches in size, operating on 25 pounds steam and maintaining tank temperatures of 180°—190° F. have been in service in approximately 10 percent nitric acid and 3 percent hydrofluoric acid in tanks measuring 3 x 4 x 4 feet. There has been no visible sign of deterioration in these units in the year or more of their operation. In the same application, no metal heat exchanger has been found that would stand up for more than a few days.

In other types of corrosive chemical operations, the "Karbate" corrugated plate heaters have greatly increased heating efficiency and reduced process costs through longer service and through eliminating maintenance costs.

Furnace Inspection

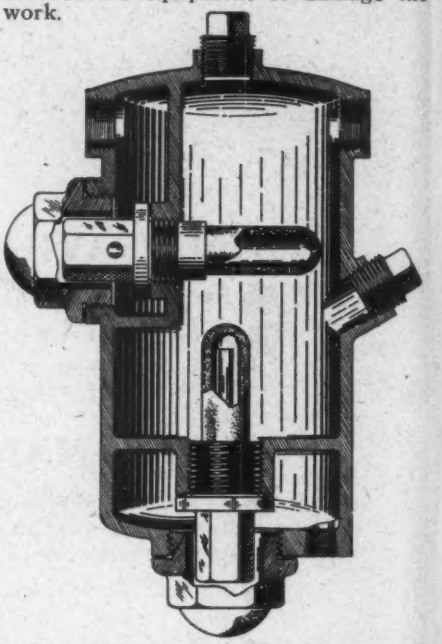
Ess Instrument Company, Fort Lee, New Jersey, announces development of "Cat's Eye," for inspection of flame conditions within a furnace or boiler firebox. Center of the eye is clear to show the flame in natural colors and the outer portion frosted to reflect changes in combustion. The instrument is described as easily attached.

Condensate Remover

Selas Corporation of America, Erie Avenue and D. Street, Philadelphia 34, has developed a device for automatic and continuous liquid-gas separation for the oil and gas industry. The "Liquijector" automatically and continuously removes condensate from compressed air and gas lines.

Action is through two porous ceramic tubes, one inherently water-repellent, the other water-permeable but air-impervious.

Among applications in which the device has been used satisfactorily are pneumatic tools, atmosphere gas generators, compressors, air-actuated control systems, vapor quench lines, spray and blast equipment, and other pneumatic apparatus in which moisture may corrode the equipment or damage the work.



Selas Condensate Remover

The basis of the product is a method for automatically separating liquid and gas phases by virtue of the surface tension of the liquid. Compressed air entering the device, passes through the first tube which is water-repellent, and is stripped of moisture by coalescence of droplets on the surface of this tube. The moisture then drops to the bottom of the unit where it passes through the second tube, without loss of air, to outside atmosphere.

Condenser-Tube Protector

Crane Packing Company, 1820 Cuyler Avenue, Chicago 13, has announced a protector for condenser-tube inlet ends, designed for protection against the destructive effects of air erosion and sand abrasion. These protectors are molded of a special wear-resistant material not affected by temperatures to 275° F. and resistant to air impingement and contaminated salt or fresh condenser circulating water. They fit inside the inlet end of the tubes, are securely cemented in place and provide a bell-mouth Venturi entrance for the circulating water. Service tests, the announcement says,

Molybdenum cast steels are meeting practically every refinery requirement involving high temperatures and pressures.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

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- IT ISOLATES
- IT QUENCHES

● Among the great discoveries of recent years is a system for using plain, ordinary water to do a quick, thorough job of quenching fires due to oil or other flammable liquids—*"Automatic" FIRE-FOG.*

By a specially designed FIRE-FOG nozzle, drops of water are "broken" into droplets—countless millions of them! The result is a heavy mist. When fire breaks out this mist, propelled at required velocity and pre-directed at vulnerable areas, finds its mark instantly. The fire is enveloped; flames are beaten down; the blaze cools; oxygen is excluded; the fire suffocates and is quenched. The entire operation is automatic, and so quick and effective that only seconds elapse before the fire is "dead."

When fire hazards are the result of ignition of fumes, leaks or breaks in apparatus, an "Automatic" FIRE-FOG installation offers protection. An "Automatic" engineer will give you detailed information.

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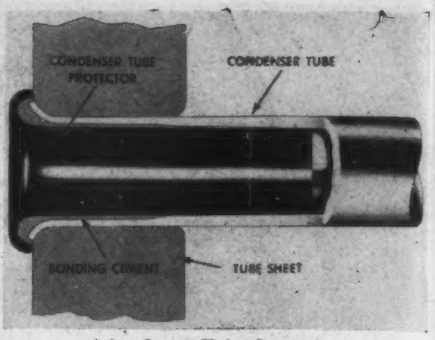

John Crane Tube Protector

show these protectors prolong tube life. They are available to fit tubes of the following sizes: ⅝-inch, 16 and 18 gauge; ¾-inch, 16 and 18 gauge, and ⅞- and 1-inch, 18 gauge.

Pipe Gauge

Three-Point Gage Company, 3821 Broadway, Chicago 13, announces a new model of its pipe gauge, to measure all sizes of pipe from ⅛- to 12-inch and all sizes of electrical conduit and thin-walled tubing.

This gauge is pocket size and consists of two pivoted steel plates with edges curved at three points for contact with the pipe or tubing to be measured, together with scales which automatically register standard sizes of metallic tubing and conduit, and also the correct sizes of pipe in terms of inside measurement. A third scale shows the right drill size for tapping. It is described by the manufacturer as one which measures by determining the outside arc at three points of contact, and by placing the two fixed contact points of one plate against the outer contour of the pipe or tubing and sliding the second or moveable plate until it makes the third contact, the markers on face of the gauge will show the size.

The new model is constructed of steel, finished in black rust proof finish, with deep etched numerals filled in with white enamel.

Step-Valve Pump

Milton Roy Pumps, 1325 E. Mermaid Avenue, Philadelphia, Pennsylvania, has designed step-valve pump for controlled volume pumping against negative differential pressures.

Outside spring-loading provides ready adjustment for desired load. The single cover plate is readily removable and provides complete accessibility without disturbing intake or discharge piping. Freedom from air-binding is obtained with minimum restriction of passages since the pumped liquid moves in an almost straight line under the ball checks.

This type valve is available in pumps with capacities from 10 up to 1300 gallons per hour.

Dual Weld-Cleaning Tool

Atlas Welding Accessories Company, 14824 Wyoming Avenue, Detroit 21, Michigan, has improved its weld-cleaning tool so that it includes a wire bristle brush and a slag removing head in one unit.

The tool features an improved brush holder which permits removal of the brush for reversing or replacement by inserting a screw-driver at the rear end of the holder. An up and outward pry releases tension and the brush pops out. For inserting the brush, the action is

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Resistance to thermal shock. Carbon and graphite do not spall or crack even under sudden and extreme changes of temperature.

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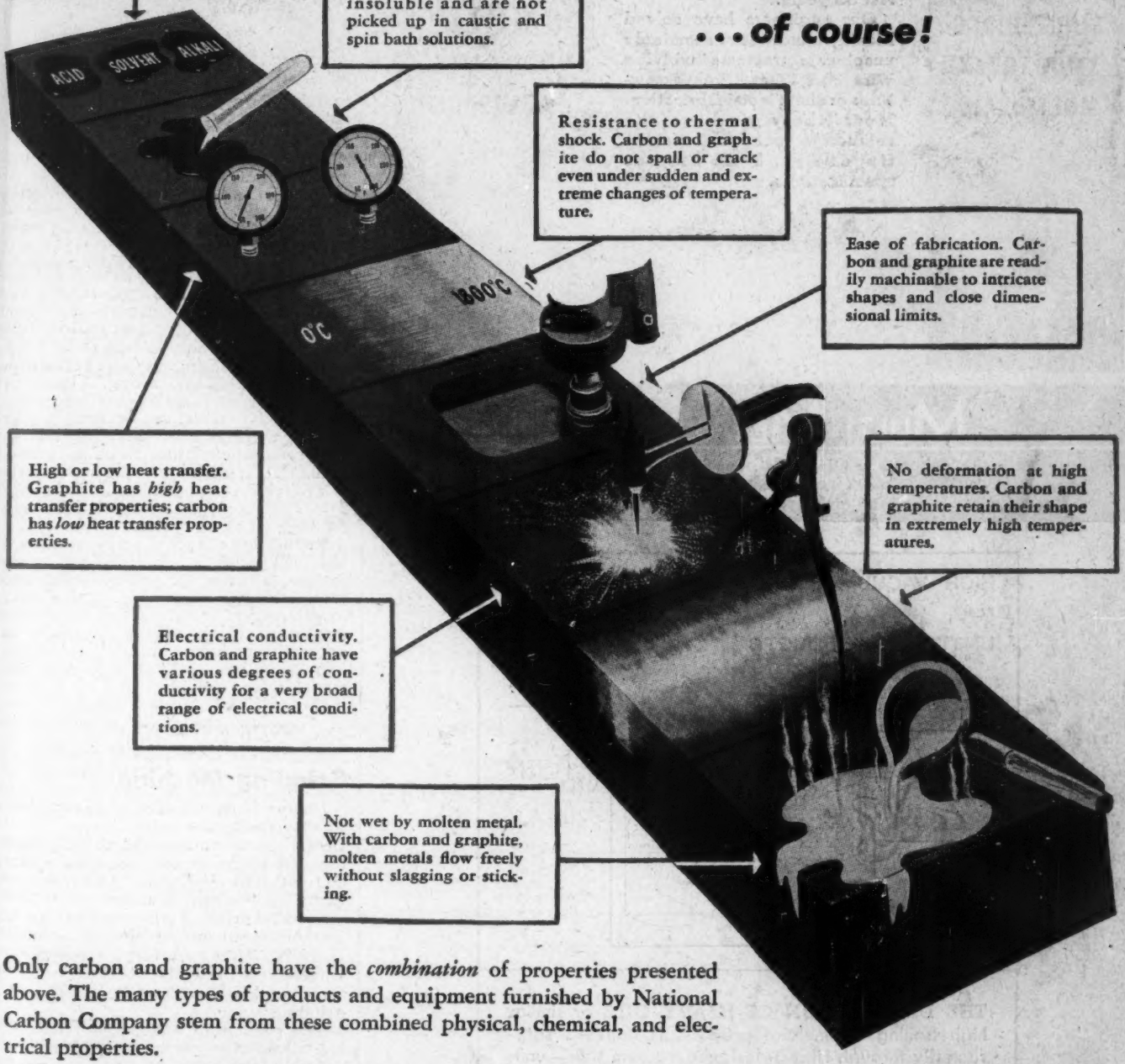
High or low heat transfer. Graphite has *high* heat transfer properties; carbon has *low* heat transfer properties.

No deformation at high temperatures. Carbon and graphite retain their shape in extremely high temperatures.

Electrical conductivity. Carbon and graphite have various degrees of conductivity for a very broad range of electrical conditions.

Not wet by molten metal. With carbon and graphite, molten metals flow freely without slagging or sticking.



Only carbon and graphite have the *combination* of properties presented above. The many types of products and equipment furnished by National Carbon Company stem from these combined physical, chemical, and electrical properties.

We urge you to study them. They not only make possible the present applications but are constantly suggesting new ones.

Many of these applications can further improve your manufacturing operations by decreasing interruptions, speeding up output, and cutting production and maintenance costs.

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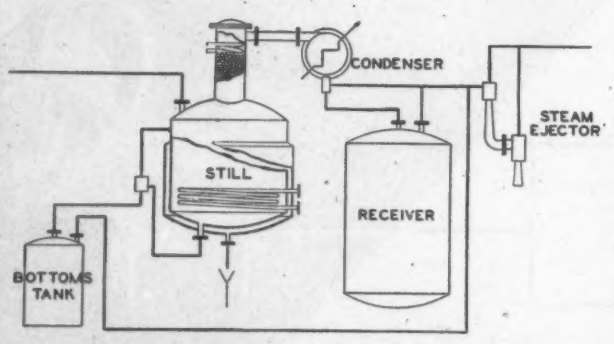

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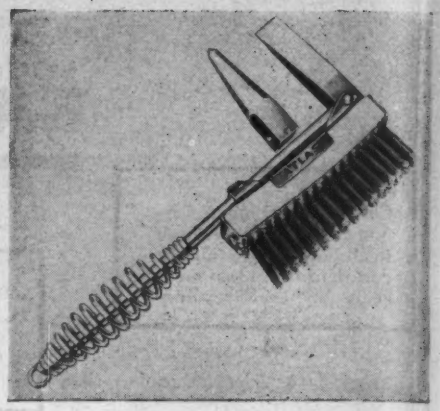


Weld-Cleaning Brush

reversed and the brush snaps in to a firm, rigid seat.

The spring-steel handgrip is permanently welded to the handle to eliminate the possibility of loosening or breaking.

Motor Starter

Allis-Chalmers Manufacturing Company, Milwaukee, has announced a new magnetic, reduced voltage cage motor starter designed to protect motors from sustained overloads, locked rotor condition, single-phasing and overloading from too frequent starting. This is accomplished in the new starter (called type ARC) with an accurately calibrated, thermal overload relay, the announcement explains. Built to general industrial applications, the new starter is available for control of motors from 5 to 2500 horsepower, up to 5000 volts, 3-phase, 50 or 60 cycles.

Reduced voltage, 2-point starting is obtained with a built-in auto-transformer, utilizing accurate, synchronous motor-driven, adjustable timing relay for transition from starting to running positions. (Units rated through 800 horsepower have built-in auto-transformers; above 800 horsepower, auto-transformers are furnished for separate mounting). Interrupting capacity rating of the new starter is ten times the motor's full load current.

Grinding Machine

Landis Tool Company, Waynesboro, Pennsylvania, announces a new No. 12 Centerless Grinding Machine recommended for most through-feed, in-feed and end-feed operations. The regulating wheel-base is self-contained.

Spindle drive is by means of an adjustable-speed motor through multiple V belts. Thus, an infinite number of wheel speeds may be obtained, through a control knob, without interrupting the grinding cycle.

The regulating wheel-base cross slide is hydraulically operated. This facilitates dressing the regulating wheel, as the wheel face is traversed across the point of a positively held diamond. The path of contact between the regulating wheel and the diamond is the same as the path between regulating wheel and work.

In through-feed grinding, no readjustment of the dresser is required when tilt of the regulating wheel-base is altered. The hydraulically operated cross-slide provides a means of accurately aligning work-rest blades. The regulating wheel-base may also be traversed by a screw adjustment to quick axial alignment of regulating and grinding wheels. The

EDWARD 6000 LB HYDRAULIC VALVES

FOR PUNISHING PRESSURES

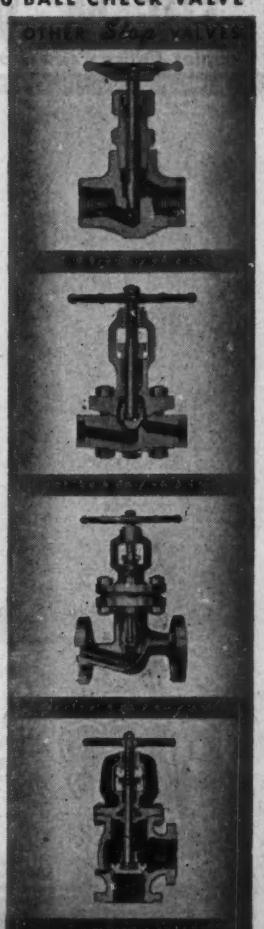
FIG. 158 Gglobe

FIG. 160 BALL CHECK VALVE

THOUSANDS of excessive pressure systems operating under 300 F depend on Edward Fig. 158 globe hydraulic valves for fast, certain shut-off or accurate pressure control.

The seat and swivel needle disk are made of EValloy, Edward's own development in abrasion resisting stainless steel. The inside screw construction, the extra deep stuffing box and the special gland and packing nut design lengthen packing life and prevent leakage along the stem. Streamlined body contours permit free flow at high velocities with low pressure drop.

These—and other—specific advantages of Edward Fig. 158 valves add up to savings in maintenance time and replacement parts. For information on valves in the Edward line write for Edward BETTER VALVES Catalog No. 101.



Corresponding ball check valves, Fig. 160, with same ratings, also available.

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For power, petroleum, chemical process, marine, technological or general industrial service
Rating 6000 lb at 125 F
Globe type, screwed or socket welding ends

SIZE	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"
End to End, Fig. 158 and 160	3¾	3¾	3¾	4½	5⅛	6½	7½	9
Center to Top Open, Fig. 158	8¼	8¼	8¼	9¼	10⅞	13¾	14⅞	18
Handwheel Diameter, Fig. 158	5⅜	5⅜	5⅜	6⅜	8½	10⅛	10⅛	11½
Weight—lbs, Fig. 158	3¼	3¼	4¾	7	12	22	37	62
Weight—lbs, Fig. 160	1½	1½	2¾	4½	7¼	13½	19¾	40

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regulating wheel-base may also be swiveled for grinding tapers.

The grinding wheel-base is also self-contained and driven through multiple V belts.

Controls are grouped at the front of the machine within easy reach of the operator. Included are a master start button for all electric motors, a master stop button and a three-stage motor-selector switch. The latter provides a work-setup stage, grinding stage and dressing stage. Regulating wheel speed automatically increases for the dressing operation. A large grinding-wheel-feed handwheel, with micrometer dial, makes possible feed settings in tenth, in terms of work diameter reduction.

Net weight of the machine, including electrical equipment, is 8000 pounds. The grinding wheel is powered by a 15-horsepower constant-speed motor.

Welding Process

The Metallizing Company of America, 1330 Congress Street, Chicago, announces the Mogul Nervous Weld process, developed to solve the problem of reclaiming defective aluminum castings. The process can be used, it is claimed, with equal success in salvaging bronze, grey iron, malleable and steel castings. Also other uses include building up of surfaces for press fits, the repair of cracked housings, motor blocks, pump housings and the preparation of surfaces for metallizing.

A complete installation to do this type of repair includes a Mogul Nervous Weld Pistol which requires approximately 60 pounds air pressure at 4 to 5 cubic feet per minute and a Mogul Nervous Weld Machine, 110, 220, 440 volts, 60 cycle or 25 cycle, single phase.

The Mogul Nervous Weld Pistol deposits atomized particles of metal which are welded to the surface and pressed leaving a metal which is welded and forged.

Designed for manual operation, the rod (aluminum, bronze or nickel) is fed through the pistol by a trigger control.

One of the advantages claimed for the Mogul Nervous Weld Pistol is that it eliminates stresses and distortion in the repair of defective aluminum castings. The temperature never rises above 125° and yet provides a deposit so dense at the point of fusion that there is no apparent line of demarcation.

Operating features of this new unit includes power chamber and peening motor, air-cooled nozzle, which keeps electrode as well as the work cooled, finger trigger which permits manual wire feed, needle valve to regulate air supply and electrode lug-connector.

Electrode Holder

A new helium-shielded arc-welding electrode holder for manual operation has been announced by the Electric Welding Division of the General Electric Company. The holder, which may be used with either helium or argon gas, is specially designed for use in the welding of light metals, such as magnesium and its alloys, where precise heat control and protection from the oxidizing effect of the air are required. It can also be used in the welding of other hard-to-weld metals, such as aluminum and stainless steel.

The holder is light and consists of a comfortable Textolite handle, a steel

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gas nozzle, and a copper electrode clamp fitted with a tool steel spring-collet. The gas nozzle is designed to give maximum coverage with minimum gas consumption, and to avoid obstructing the operator's view of the arc. A fixed angle of 76 degrees between the nozzle and the handle contributes to the balance and "feel" of the holder. The electrode clamp is constructed to hold a tungsten or a carbon electrode until all but a ¾-inch stub is consumed. The holder may be laid down without arcing, since the handle, gas nozzle, and electrode clamp are fully insulated.

A button for controlling the gas-supply valve is located on the handle of the holder, where it is convenient to the operator's thumb. This button will remain in either the on or off position without being held. It also operates the valve in intermediate positions, thus providing smooth, stepless control of the gas flow and enabling the operator to conserve helium when welding in a corner or a depression.

A feature of the new holder is the tapered friction joint between the electrode clamp assembly and the handle, which facilitates rapid change of electrode size without using tools or making threaded connections. Electrodes of various sizes may be left in their respective clamps and substitution made merely by removing one assembly from the handle and slipping on another.

Fork Lift Truck

Towmotor Corporation, Cleveland 10, Ohio, has developed a fork lift truck with a wider range of capacities for lifting, moving and stacking all types of materials—Model LT-50.

Available in a 5000-pound capacity with either 104- or 144-inch lift, or in a 4000-pound capacity with 144-inch lift, Model LT-50 replaces Models LT-46 and LT-53 and rounds out the line of "one man gangs" offered in wheelbases of 40, 44, 50, 56, 62 and 72 inches and having corresponding ranges of speed, load and lift capacities.

Maximum travel speed of Model LT-50 is eight miles an hour; loaded lift speed is 40 feet per minute. A 50-inch wheelbase, outside turning radius of 92, overall width of 42 inches, overall length, less forks, of 88 inches and center underclearance of 6 inches, permit maximum maneuverability in close quarters, along narrow aisles and over steeply angled ramps. Standard fork equipment is of 36-inch length.

Goggle Cleaning Cabinet

Mine Safety Appliances Company, Braddock, Thomas and Meade Streets, Pittsburgh 8, Pennsylvania, has developed the M.S.A. goggle cleaning cabinet to encourage workmen to wear their goggles and keep them clean.

The cabinet is compact in size and is equipped with Fogpruf, an efficient lens cleaning and anti-fogging agent, and optical wiping tissues. The unit is ideal for mounting in strategic work locations and in repair rooms, tool rooms, locker rooms or on traveling goggle dispensing carts. Two vials of Fogpruf are concealed within the dispensing block permitting the cleaning of two pairs of goggles at one time. A tap on either button of the dispenser sprays Fogpruf on the lens. Cleaning tissues are withdrawn from an opening in the top of the dispensing station.

A sliding panel permits quick replacement of Fogpruf and tissues, also making accessible a compartment for an additional supply of Fogpruf.

Plastic Stock Room Cards

Plastic Division of Hollywood Athletic Company, 211 E. 7th Street, Los Angeles 14, California, announces stockroom bin card holders made of ivory plastic availabie in a variety of shapes and sizes.

Applicable to any flat surface—on wood by means of tacks, for which holes are provided, or on metal with glue, they consist of the plastic holder itself, an insert tab on which description of the article may be typed, and a covering sheet of transparent plastic.

Plastic Goggle

U. S. Safety Service Company, 21 West 10th Street, Kansas City 6, Missouri, announces "Saf-I-Shield," an all-purpose goggle made of non-inflammable plastic. Design permits clear vision front and side, and wearing over glasses, and is so constructed as not to be scratched when placed on table.

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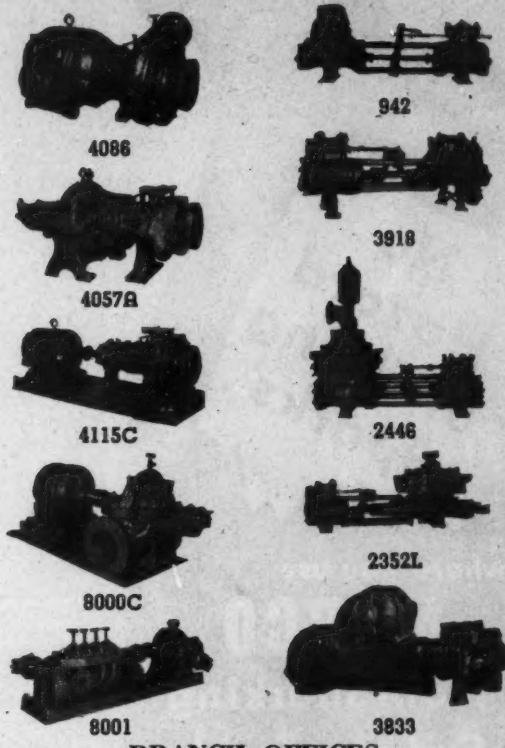

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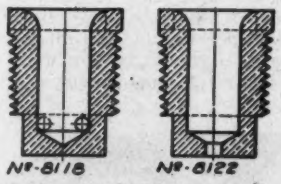
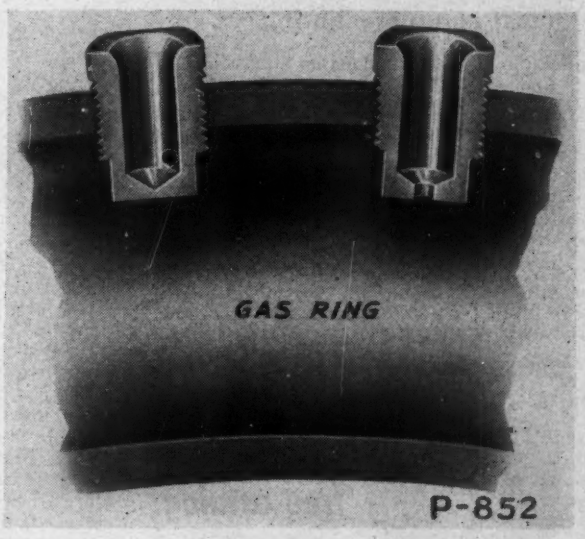
provide many operating advantages

The National Airoil patented* design Gas Tip is a decided improvement over the conventional type gas tip for cylindrical, ring gas burners, as well as pipe gas burners.

This gas tip, as can be seen in the illustration, has the orifice immersed in the gas chamber so that the orifice is protected from overheating, oxidizing and coking by the cooler gas in the ring. Also, the gas orifice being located in the cup, is screened from most of the radiant heat of the furnace. Because of these features, the gas tips are practically free from clogging or deterioration, even after a long period of continuous operation.



*U.S. Patent No. 2,160,615



National Airoil Gas Tips are furnished in ¼" and ⅜" pipe size, and are made as standard in carbon steel and special in ceramic materials.

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☆ BUSINESS NOTES ☆

Graver Tank & Mfg. Co., Inc., East Chicago, Indiana, has announced election of J. E. Swanson as a vice president of the company. Swanson, who has been with the company for more than 25 years, has served in various executive capacities for the organization, having most recently held the position of general manager of sales.

J. E. Swanson

Pomona Pump division of the Joshua Hendy Iron Works has moved its administrative offices to Sunnyvale, California, for a consolidation with the general administration of the company. Affected by the change are the sales, engineering, purchasing and accounting departments. Among those moving their offices north are Arnold Brown, sales manager; A. W. Moore, advertising manager, and Ralph Linderman, export manager. All manufacturing activities will continue to be carried on at Pomona and Torrance, California, with Charles L. Barrett as plant manager for both.

The International Nickel Company announces that H. O. Teeple, chemical engineer, has joined the technical service group of the development and research division of the company at New York, and will specialize in corrosion problems. After graduation from the University of Michigan in 1937, Teeple became associated with the alkali and chlorine products industry, remaining there until coming to International Nickel Company. He has had experience in production, process control, and maintenance engineering, including equipment specifications, corrosion control and the use of metals, alloys, plastics, and special paints.

Rheem Manufacturing Company has acquired Atlas Steel Barrel Division of Bethlehem Steel Company at Bayonne, New Jersey. Robert Campbell, president of Atlas Steel Barrel Corporation before its acquisition by Bethlehem, and since then manager of the plant, has been made a vice president of Rheem Manufacturing Company.

The Marley Company, Kansas City, Kansas, announces that Ray T. Jenkins and Joseph H. Cameron have been elevated to vice presidencies. Jenkins, now general sales manager at the main office in Kansas City, has been succeeded as director of the company's Houston division by Joe T. McKinley. Cameron continues in charge of the Eastern Seaboard division with offices at 2 Rector Street, New York. W. R. Kell, former vice president and general sales manager of the company, has retired.

J. H. Cameron R. T. Jenkins

Westinghouse Electric and Manufacturing Company, Steam Division, Philadelphia, has announced appointment of Floyd T. Hague as assistant to L. E. Osborne, vice president and manager of the division. C. B. Campbell has been named manager of engineering, filling the place left vacant by Hague, and J. S. Newton was appointed assistant manager of engineering. Realignment in the engineering organization, it was explained, will facilitate wartime activities in steam-turbine engineering and in developments expected to lead to gas-turbine production after the war.

Manning, Maxwell & Moore, Inc., Bridgeport, Connecticut, announces that Harry W. Gray, until recently assistant to the general sales manager of the Airtemp Division of Chrysler Corporation, Dayton, Ohio, has joined its organization. Gray, a graduate of Purdue, 1928, in mechanical engineering, has spent a number of years with large industrial concerns as director of service on product development and field research. He will devote his time to market analysis.

H. W. Gray

The Duraloy Company, Scottdale, Pennsylvania, announces appointment of F. S. Wynans, formerly of the planning staff of Carnegie-Illinois Steel Corporation, as secretary-treasurer of the company.

Mixing Equipment Company, Rochester, New York, has appointed Edgar A. Rogers exclusive representative in Georgia, Alabama and a major portion of Tennessee. Rogers has many years experience in consulting and sales work in chemical and process industries. He will have headquarters in Chattanooga Bank Building, Chattanooga, Tennessee.

Busch-Sulzer Bros.-Diesel Engine Company, St. Louis, has elected Norris H. Schwenk its president to replace Edward B. Pollister who has retired. Schwenk, at one time president of De La Vergne Engine Company, more recently has been an executive of Baldwin Locomotive Works.

Jones & Laughlin Supply Company has announced appointment of Seymour S. Baker as district representative of the company's construction and engineering division for the Gulf Coast area, with headquarters at Houston. Baker has been associated with design and construction activities in the petroleum industry for the past 20 years in the employ of operating companies, and has

One million feet—that's a lot of Republic Pipe and Tubing—and that, approximately, is the amount installed in the mammoth new Cities Service Refining Corporation plant at Lake Charles, La.

This footage includes both Republic Continuous Weld and Electric Weld Pipe—with sizes ranging from ¼" to 16" O.D. Part of the footage is represented, too, by Republic Electrunite Heat Exchanger Tubes. And, in addition to tubular goods, about five tons of Republic Upson Quality Bolts were used.

All through the petroleum industries—in production, refining, by-products and transportation—you'll find Republic Steels and Steel Products helping to make possible today's miracles, and helping to keep costs in line by always giving the service demanded of them.

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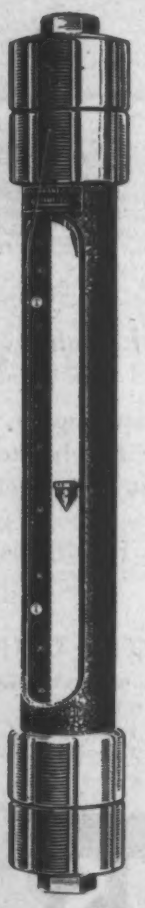

COCHRANE-ROTAMETERS INC.
ROTAMETERS

handled contract assignments in the East and Southwest.

Ethyl Corporation is producing more tetraethyl lead for military purposes alone than was used in all the automobiles and airplanes in the United States and the Allied nations in 1940, it was brought out in a statement by Earle W. Webb, the company's president, issued following orders from PAW limiting use of lead in civilian gasoline. Expressing his approval of the action of PAW, Webb said the ever-increasing demand upon the petroleum industry to supply gasoline of highest quality to the armed forces made it necessary to restrict civilian gasoline quality. There is ample supply of tetraethyl lead in stock piles throughout the Allied countries to meet military requirements, he said.

Kieley & Mueller, Inc., North Bergen, New Jersey, has appointed Stanley L. Burgess, 6432 Cass Avenue, Detroit, its agent in the Detroit area for its line of pressure reducing valves, liquid-level controls and regulating valves.

Pennsylvania Salt Manufacturing Company announces opening of a district sales office at Cincinnati, Ohio, to serve Southeastern Indiana, Southwestern Ohio, and Kentucky. Louis M. Kuilema, who has been appointed district sales manager in charge of the office, was formerly with the Paper Makers Chemical Department of Hercules Powder Company and has been in the executive offices of that company in Wilmington, Delaware, for the past seven years.

The Cooper-Bessemer Corporation, Mount Vernon, Ohio, announces that it has inaugurated an apprentice-training program in cooperation with the rehabilitation division of the veterans Administration. A four-year apprenticeship course of shop work and related class-room instruction will lead to a job with the company at journeyman's wages. During training the veterans will receive standard apprentice wages supplemented by a government grant which will total a journeyman's pay.

Steel and Tubes Division of The Timken Roller Bearing Company, Canton, Ohio, has announced that Brace-Mueller-Huntley, sales representative for Timken electric furnace alloy steels and Timken seamless alloy steel tubing, also has been appointed representative for Timken stainless steels. The distributor will stock stainless steel for direct shipment from warehouses at Buffalo, Syracuse and Rochester, New York, and Montreal and Toronto, Canada. Stainless steel seamless tubing will be available through the distributor for direct mill shipmen'

Talon, Inc., Steel Tube Division, Oil City, Pennsylvania, announces that Robert A. Campbell, sales manager, has been appointed general manager and will combine the duties of the two positions.

Attapulgus Clay Company and Porocel Corporation, Philadelphia, have announced appointment of W. S. W. McCarter as director of research and development of the two companies. He is a graduate of Pennsylvania State College and has been research super-

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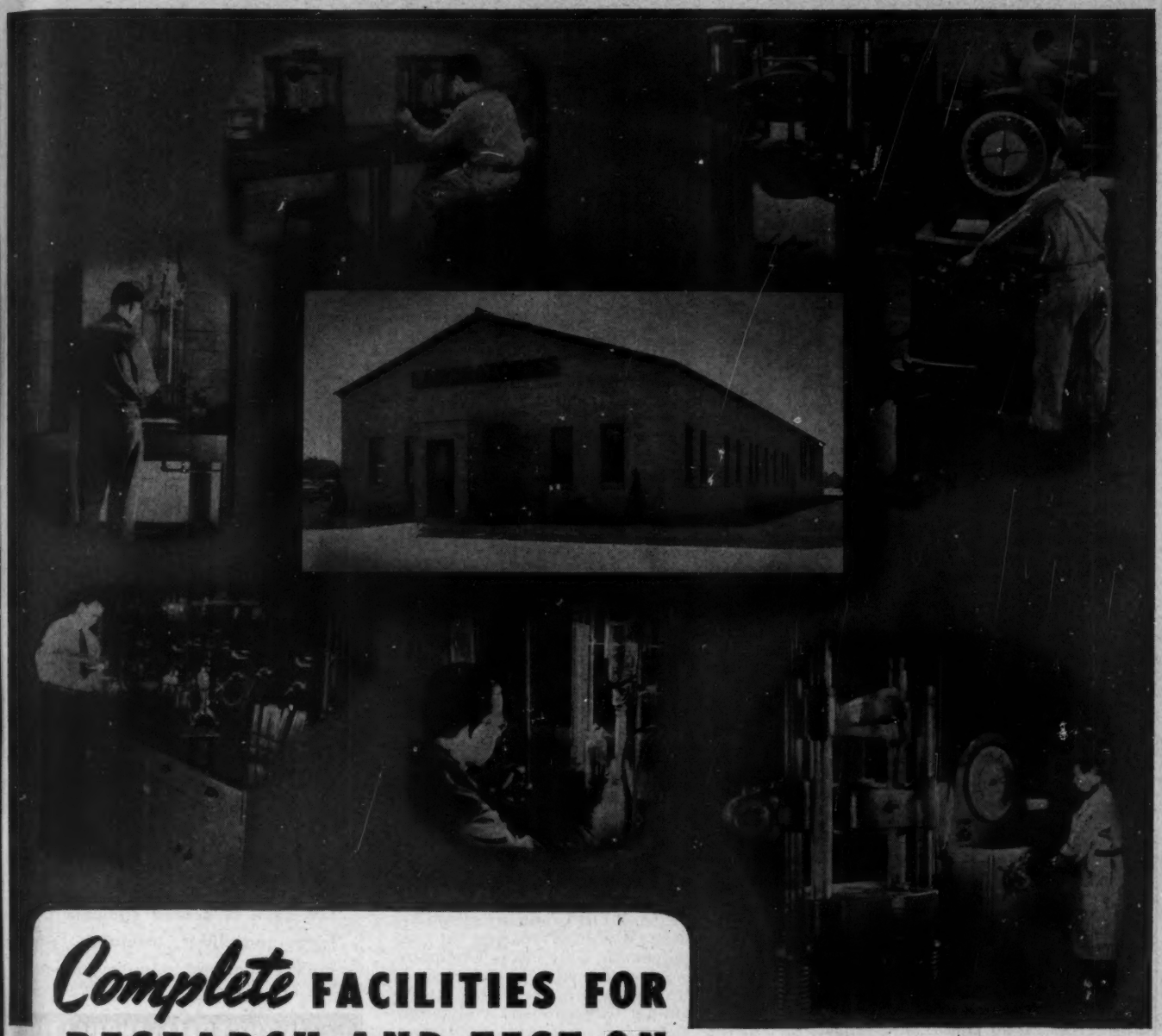

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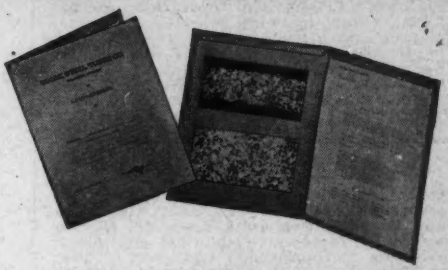

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GLOBE STEEL TUBES CO. *Milwaukee 4, Wisconsin, U. S. A.*

visor of the companies for the past four years.

Hooker Electrochemical Company, Niagara Falls, New York, recently was awarded a third star for its Army-Navy E.

Hanlon-Waters, Inc., Tulsa, has been awarded a white star to its Army-Navy "E" pennant.

Edmund H. Lunken, chairman of the board of The Lunkenheimer Company, Cincinnati, died July 19, at his summer home in Michigan. The son of Frederick Lunkenheimer, founder of The Lunkenheimer Company, at the age of 16 entered his father's business which had been established in 1862. Upon the death of his father in 1889, he assumed leadership of the company. In 1892, he legally changed his name to Lunken, but did not change the name of the company.

Homestead Valve Manufacturing Company, Coraopolis, Pennsylvania, has been awarded the third gold star for the Maritime "M" Pennant.

De Laval Steam Turbine Company, Trenton, New Jersey, has been awarded a fourth star for its Army-Navy E pennant.

Tube Turns, Inc., Louisville Kentucky, has been awarded additional stars for its Army-Navy E and Maritime M.

The Foxboro Company, Foxboro, Massachusetts, has had an additional star added to its Army-Navy E.

New York Purchasers Group Elects Bratches Chairman

The oil company buyers' group of the Purchasing Agents Association of New York has elected as its chairman, W. H. Bratches, manager of purchasing and stores for Shell Oil Company. Bratches succeeds R. M. Morrison, general purchasing agent for The Texas Company, who was elected national chairman of the Oil Company Buyers' Group at the recent annual international convention of the National Association of Purchasing Agents. The membership of the New York group consists of purchasing agents actively engaged in this area in the procurement of material and equipment for domestic and foreign petroleum operations.

Kellogg Sponsors Two Scholarships at Tulsa

The M. W. Kellogg Company has arranged the sponsorship of two scholarships in the College of Petroleum Engineering at Tulsa University. The scholarships have been set up in accord with the general pattern followed by most of the oil-refining profession in endeavoring to secure the finest type of personnel.

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